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Observations of Continental European Solid Waste Management Practices

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Solid waste management practices in Germany, Switzerland, Holland, Sweden, Denmark, and France were observed, and selected European and American solid waste management practices were compared. The U.S.--German Cooperative Program on Natural Resources, Pollution Control, and Urban Development provided the mechanism for the 90-day study. The report is not intended as a critique of European solid waste management practices since many sections of the report are based on random observations of partial day's operations. A selected list of contacts and operations observed is included in the report.

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Observations
of
Continental European
Solid Waste Management Practices

by MICHAEL E. JENSEN

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Public Health Service
CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE
Environmental Control Administration
Bureau of Solid Waste Management

1969

Preface

THESE ARE FIRST-HAND OBSERVATIONS of some of the solid waste processing operations seen on the Continent in the summer of 1967. The report may be considered as the third of a trilogy—three publications resulting concomitantly from the Bureau of Solid Waste Management's interest in international information exchange, and the June 1967 International Association of Public Cleansing (INTAPUC) meeting in Paris. The latter was attended by a team of U.S. solid waste management experts, who, following the INTAPUC meeting, made a tour of solid waste processing operations in Germany before returning to the States.

One of the members of the U.S. Study Team remained on the Continent to write up the report for the Study Team on solid waste management in Germany.[1] The same author then gathered data for a second report, now published, on European operations.[2]

This, the third report, was written by a staff engineer of the Bureau of Solid Waste Management, assigned to a 90-day tour of duty with the U.S.–German Cooperative Program on Natural Resources, Pollution Control, and Urban Development. In addition, the author attended the INTAPUC conference, accompanied the U.S. Study Team to Germany, and then toured Switzerland, Holland, Sweden, Denmark, and France, to observe and compare selected European and American solid waste management practices. The result is intended not as a comprehensive critique, but rather as an overview of certain continental European solid waste operations as observed with intellectual curiosity and a fresh viewpoint.

Two of the conclusions are of current interest. The author indicates (despite the to-do about European 'advanced' solid waste management techniques) that European practices are not using an advanced technology. Instead, the economic situation is such that a more expensive system for refuse disposal can be justified. The author also demonstrates well the importance of the international solid waste field as an extension of the basic value of the regional approach to the management of solid wastes.

—RICHARD D. VAUGHAN, *Director*
Bureau of Solid Waste Management

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[1] HART, S. A. Solid wastes management in Germany; report of the U.S. Study Team. Public Health Service Publication No. 1820. Washington, U.S. Government Printing Office, 1968. 18 p.

[2] HART, S. A. Solid waste management/composting; European activity and American potential. Public Health Service Publication No. 1826. Washington, U.S. Government Printing Office, 1968. 40 p.

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I. Introduction

BEGINNING 12 April 1967 the writer was engaged in a 90-day assignment with the U.S.–German Cooperative Program on Natural Resources, Pollution Control, and Urban Development. Encompassed by the program were water pollution control, electric power management, coal research, air pollution control, solid waste management, urban planning, and noise abatement. The German program director was Dr. Joachim Berg, Ministerraldirektor (Assistant Secretary) of the German Ministry of Health, and the U.S. program director was Dr. James Slater, International Activities Assistant, U.S. Department of the Interior.

The Bureau of Solid Waste Management of the U.S. Department of Health, Education, and Welfare early recognized the desirability of international information exchange to aid in developing a new program such as ours. As a first step, a contract to study European composting practices was developed with Dr. Samuel A. Hart, professor of agricultural engineering, University of California at Davis. In addition, it seemed desirable for a Bureau of Solid Waste Management representative to observe and compare European and American solid waste management practices. The U.S.–German Cooperative Program provided the mechanism for such an assignment.

Germany was the study base, but in the short time available an attempt was made to observe selected operations in Switzerland, Holland, Sweden, Denmark, and France. German practices seemed representative of continental European practices, although this report, of course, is not a critique of European solid waste management practices, since many sections of the report are based on random observations of partial day's operations.

This report deviates slightly from most general reports by not including general plant design value data; unless there was a radical departure from accepted design values, the reporting of such data seemed needless repetition of published information.

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II. German Organizations Concerned with Solid Wastes

SEVERAL German organizations are active in the solid waste field. The German equivalent to the IRGRD (International Research Group on Refuse Disposal) is the IAM (International Arbeitsgemeinschaft für Müllforschung); the equivalent of the American APWA (American Public Works Association) is the VKF (Verband Kommunaler Fuhrparks - und Stadtreinigungsbetrieb). The AKA (Arbeitsgemeinschaft für Kommunale Abfallwirtschaft) was originally developed to help promote the practice of composting; over the years, however, the interests of the group have grown until now it is concerned with all aspects of solid waste management. In the past the AKA published information sheets for communities, and the members served as community solid waste management consultants. At present, the AKA is cosponsoring a two-volume looseleaf publication titled *Müll und Abfallbeseitigung* (Garbage and Refuse Disposal). Various sections relating to different aspects of solid waste management are written and kept current by committees of experts and authorities. This publication is an excellent source of information on the present theories and practices in German solid waste management. A fourth German organization, the Zentralstelle für Abfallbeseitigung (Central Office for Solid Waste Disposal), closely parallels in its development that of the Bureau of Solid Waste Management.

ZfA: "The German Solid Wastes Program"

OVER THE YEARS it became evident that the many organizations with solid waste interests in Germany were not able to cope individually with the rising problems of refuse disposal, so that a government agency was needed. Various proposals for a new agency included representation and financial support from the federal government, state governments (11 German states), municipal governments, and industry. The proposal that was finally accepted created a new office in the Ministry of Health, but was financed only by the federal and state governments. With federal and state government approval, the Zentralstelle für Abfallbeseitigung (ZFA) was created 1 October 1965.

The usual organizational complications delayed the beginning of an active program until about July 1966. The ZFA operates under a three-year contract with the federal and state governments; at the end of that period a decision will be made on contract continuation.

The ZFA has three major responsibilities: (1) to provide technical services or assistance to the communities. Part of this responsibility will be accomplished by the development of fact sheets and guidelines; (2) to propose and develop minimum standards for the construction and operation of solid waste management facilities; (2) to encourage and coordinate research efforts for the advancement of solid waste management. The ZFA is to carry out these tasks on a yearly budget of DM 300,000 ($75,000) or about 1/7 cent per person. This can be compared to about 8 cents per person for the U.S. program.

At the time of writing, the ZFA professional personnel were as follows: Mr. M. Ferber, Chief; Mr. H. Seng, Assistant Chief; Mr. H. Lauer and Mr. H. Leonhardt, Staff Engineers.

At the state government level there is another organization of interest. This is the Solid Wastes Unit of the Ruhr Regional Planning Authority that operates in the State of North Rhine–Westphalia. The unit, Auskunfts- und Beratungsstelle Müll (Refuse

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Disposal Information and Consultation Agency) is referred to as ABM, and was organized in the fall of 1966. ABM currently consists of four professional personnel with Mr. W. Schenkel in charge.

The area subject to the Ruhr Regional Planning Authority comprises about 1,776 square miles (4,600 sq kilometers) and includes a population of about 5.7 million persons, or more than one-tenth of the population of the German Federal Republic. The area extends from the Dutch border on the west to a line east of the cities of Hamm, Dortmund and Hagen, and from the Lippe River Valley on the north to the Ruhr River Valley on the south. The Authority's domain covers the area containing most of the coal reserves and most of the iron and steel production, as distinguished from fabrication, in West Germany.

As is well known, the Ruhr Region is one of the most industrialized and densely settled parts of the world. Its rich coal reserves gave rise to its vast iron and steel industry. The coal and steel complex led, in turn, to the development of steel fabrication, chemical and other industries, which are technologically or economically linked to coal and steel. In 1962 the Region produced 116 million tons of coal, which was 82 percent of the West German production and 51 percent of the six-nation European Coal and Steel Community's output. The same area produced 22.2 million tons of steel or 78.2 percent of the West German and 31 percent of the Coal and Steel Community's production.

Approximately 55 percent of the employment in this Ruhr Region is in mining and manufacturing. About 17 percent of the Region's employment is in mining, 25 percent is in iron and steel production, 2.2 percent in chemicals and oil refining, and 11 percent in other manufacturing. Some of the Region's most serious problems, such as unfortunate mixtures of industry and housing, insufficient economic diversification, and a lack of job opportunities for women, are related to the dominance of the coal–steel–heavy-industry complex in the Ruhr. Of late, however, there has been a trend toward greater diversification with a decrease in the relative importance of mining within the Ruhr.

Recently, it became evident that the Ruhr Regional Planning Authority should include solid waste management in its responsibilities, and since a similar need existed for the State to avoid wasting resources, the State granted ABM the authority for solid waste management planning for the entire State of North Rhine–Westphalia, not just the confines of the Ruhr River Basin.

The ABM does not intend to duplicate the responsibilities of the ZfA, but it will perform an active role in assisting the ZfA in its work. The ABM's first responsibility is to develop a regional plan for solid waste management and make certain existing or proposed practices conform to the plan. It is interesting to note that if necessary to ensure the regional approach to solid waste management, the ABM has the authority to construct and operate solid waste disposal systems. The second responsibility of ABM is to provide information that relates work performance to official fees charged.

Because the Planning Authority is composed of representatives of all community governing bodies and special interest groups, and operates on the concept of the regional approach to the solution of a problem, all those in the solid waste field will be interested to see how desirable results are achieved.

III. Refuse Characterization

AT THE INTAPUC CONFERENCE (International Association of Public Cleansing, Paris, June 26 to 30, 1967) Dr. Ing. Hans Straub (Head, Town Planning Department of Baden-Baden, Germany) presented a compilation of data on composition of municipal refuse for central Europe:

COMPOSITION OF CENTRAL EUROPEAN MUNICIPAL REFUSE [3]

	Amount (kg/capita-year)	Water (%)	Organic matter (%)	Minerals (%)
Domestic refuse	200–250	20–45 (40–110 kg)	30–34 (60–85 kg)	34–45 (85–110 kg)
Sludge (dry)	25–30	——— ———	50 (12.5–15 kg)	50 (12.5–15 kg)

[3] STRAUB, H. Agricultural value of municipal refuse. Presented at International Association of Public Cleansing, Paris, June 26–30, 1967.

The data developed by Dr. Straub showed domestic refuse plus sewage solids to average about 85 kilograms [4] organic matter per year, or approximately 230 grams per capita-day. On this basis he calculated that the German population produced about 1.7 million tons [5] per year compostable municipal refuse, while stable litter amounted to 18 million tons per year. He then noted it would be no problem to dispose of the municipal manure along with the stable litter, if the compostable portion of the municipal manure were not so disguised and confused with other materials when delivered, and if the disposal of stable litter were not a problem.

Discussions with public cleansing officials found an estimated 0.8 to 1.2 kilograms per capita-day of domestic refuse is produced while Dr. Straub's data compilation reported 200 to 240 kilograms per capita-year. Probably the difference in the values can be explained by the uncertainty of the number of days per year used for the calculations and the possibility that Dr. Straub's compilation did not reflect recent changes in the quantities of refuse produced. Dr. Straub reported that out of the 200 to 250 kilograms per capita-year of domestic refuse, 30 kilograms are nonburnable and noncompostable, 6 to 7 kilograms of material would be best disposed of by incineration, leaving 160 to 215 kilograms per capita-year of compostable material. It should be noted here that all the material in domestic refuse under the generic name of organic matter is not necessarily readily decomposed by microorganisms.

German solid waste authorities feel the German solid waste character is following an evolution similar to that of U.S. refuse but lags about 10 years behind. Thus, data characterizing the present U.S. refuse would be very useful to the Germans in planning and developing programs for effective solid waste management. As another source of in-

[4] 1 kilogram = 2.2 pounds.
[5] For this report, a ton is to be considered a metric ton, or 2,240 pounds.

formation for future planning, a committee of government and industrial experts has been formed. The committee will work closely with industry in analyzing German estimated future products and markets and, hopefully, be able to indicate future solid waste management problems.

Visual observation of German refuse revealed fewer beer cans but more wine bottles, and the same types of voluminous paper products but fewer paper grocery bags. The amount of garbage or food wastes appeared comparable to that in the United States but this was probably deceptive because of the wrapping of the garbage. Garbage grinders are prohibited in Germany.

The ash content was greater than that in the U.S. refuse but has been rapidly decreasing over the past years as oil and gas home heating become more common. The ash content helps lower the refuse moisture content to about 30 percent in winter, and garden clippings and vegetable wastes produce a 40 to 50 percent summer moisture content. The heating value of the refuse ranges from 1,600 to 4,500 Btu per pound compared to the 3,000 to 5,000 Btu per pound in U.S. refuse.

Reports have been made on the refuse composition of several large cities, but there was no indication that special analytical techniques had been developed. German solid waste personnel are interested in developing usable standard methods for refuse analyses, but it was not evident that any work was being done at present.

IV. Collection

IN OBSERVING German refuse collection operations, two features were immediately noted: the use of heavy-duty standardized containers and the mechanical emptying of the containers. The collection vehicles generally have smaller capacity than those in the United States and are not equipped with compaction devices. The collection crews range from three to five men and use a variety of methods similar to those used in the United States to bring the refuse from the house to the truck.

The containers, nearly always city owned, are of a standard 33-liter (8.7-gallon) or 110-liter (29-gallon) capacity, made of heavy-gage galvanized metal with a heavy supporting flange on the bottom, lifting bails or handles, and a heavy hinged lid. When most of the residences were heated by coal or wood, such a heavy-duty container was required to support the weight of the ashes and to survive fires resulting from hot ashes being placed in the refuse. The containers are very durable, and some of those still being used were purchased before 1940.

With the tare weight of the 110-liter container being about 20 kilograms, the empty container is difficult enough to carry; but when full, it is too heavy for one man to lift. The full containers are moved in the same manner as heavy barrels. The man, wearing a heavy leather glove, grasps the lid of the container by a large round, knob-like projection, tips the container toward him, and with his free hand begins to rotate the edge of the container. The container is balanced and supported on the heavy-duty bottom flange while being rolled to the truck. Positioned behind the truck so that two hinge points on the container are aligned with lifting supports on the tipping mechanism, when the tipping mechanism is activated, the container is lifted and rotated through an angle of about 135° about its hinge points. While being lifted and rotated, the container engages a hood with a movable flap. The top of the container is inside the hood during discharge, thus any dust is retained in the truck.

It was repeatedly pointed out that the increasing use of oil and gas heat in the homes had drastically reduced the refuse ash content in recent years. The U.S. Study Team, during their inspection, noted that while the dustless collection system was well designed for dealing with the ash problem, it would not be efficient for handling large amounts of bulky material.[6] Since the German collection system is almost exclusively based on the dustless system, it appears that the changing nature of the refuse will require an extensive modification of the collection system in the future.

The present practice is to provide twice-a-week household collection of anything that will go in the container. Service is usually provided on Monday and Thursday, or Tuesday and Friday, while on Wednesday, most of the collection crew is assigned to street cleaning and special collection of bulky items. Commercial or business areas are serviced daily.

The collection and disposal operations are usually financed by an annual tax fee. Based on the monetary exchange rate, the U.S. and German charges seem to compare, but based on the more realistic purchasing power conversion, German rates would be significantly greater; yet the rates are not adequate to support the operations.

Large bulk-type containers and transporters are in general use, and the U.S. and Ger-

[6] HART, S. A. *Loc. cit.*

man equipment and systems are similar. Paper bags are being experimented with on a small scale, most notably in parks and roadside stops. There is also a trend to replace the standard metal container with a plastic one of the same design. With the trend of increasing refuse bulk, it will be interesting to observe what changes in container design will occur and how soon they are developed.

A unique collection operation observed was the pneumatic transport system at Sundbyberg, Sweden. The system was designed to collect the refuse from a newly developed high-rise apartment complex. The complex is built in a well-landscaped, rolling, wooded area, and unfortunately for underground construction projects, the ground is mostly rock. The system began operation in 1965, serving 15 collection chutes and by 1967 was serving 36 chutes that received refuse from about 1,100 apartments, or about 2,000 people. Eventually the system will be transporting refuse a maximum distance of about a mile while serving approximately 5,000 people.

The refuse is placed into the system through the refuse chute that is standard design in a high-rise building and normally specified by standard building codes. At the bottom of the chute, an enlarged section of pipe connects the refuse chute to the transport line. The pipe provides some additional storage capacity. A valve designed to control the entry of refuse into the transport pipe also serves to maintain the line vacuum while avoiding a vacuum on the refuse chute. When activated the valve requires 1.5 seconds to either open or close, and the period of time it remains open can be adjusted in accordance with the frequency of collection and the amount of material in the chute.

The system uses 24-inch-diameter welded steel pipe buried 3 feet underground. Compressed air and electric lines to operate the chute discharge valves are placed adjacent to the vacuum lines for easy access. The vacuum lines operate with about one-quarter atmosphere (about 4 psi) vacuum pressure; the compressed air line pressure is about 6 kilograms per square centimeter.

The vacuum transports the refuse through the pipes at velocities of 70 to 90 feet per second, thus requiring only seconds to travel from the chute to the storage silo. The silo is a 50-cubic-yard steel tank insulated to prevent the refuse from freezing in the winter.

The vacuum is produced by five standard turbines; four are used for operation and the fifth is kept on standby. Each turbine uses a 110-kilowatt electric motor and has a power consumption of about 80 kilowatts while operating. Present operation with the system not fully automated requires the turbines to operate for about 1.5 hours during each collection. The dusty air drawn through the system is cleaned by six bag filters and moved through a muffler and baffle system that is very effective in reducing the noise level. Periodically, the dust is shaken from the filters and flushed with water into the sewer.

When the system is fully automated, it will operate as follows. At a preset time for collection, the control monitor will start the turbines. When the required line vacuum is reached, the first refuse chute-valve will be activated, and each chute-valve on the system will be automatically operated in accordance with a desired pattern until the designated area has been serviced, at which time the turbines will be stopped. In the event of a malfunction, the monitor will sound an alarm for the operator, and then skip over the malfunction and continue with the rest of the system. In the present situation, the operator starts the turbines and then travels by bicycle to the buildings and activates the valves.

It is recommended that pipes not smaller than 400 millimeters (about 20 inches) in diameter be used, and 5/16 inch for wall thickness has been found adequate. As stated previously a vacuum of one-quarter atmosphere is sufficient and produces a refuse transport velocity of about 70 to 90 feet per second. Refuse is reported to have a flow resistance of about 1 millimeter per meter of travel in the pipe. Studies found that erosion from the movement of the material is not measurable, and the hypothesis is that the high transport velocity results in the material traveling in the middle of the pipe surrounded by an air cushion. If

it is necessary to elevate the refuse, it is recommended that a spiral with an inside diameter of three times the pipe diameter be used, and a vertical angle of 30° should not be exceeded. It is estimated that for this system to serve a block of 1,000 apartments the capital cost and annual operating cost per apartment would be about $336 and about $7, respectively.

The only complaint made about the system was that the bulky materials were not collected. The refuse chutes used restricted the diameter of material to less than 12 inches and the unbendable length to less than 2 feet, and so far the system has been able to cope with the materials that ingenious people can manage to put into the chute. There was little noise connected with the system. The exterior noise of the turbine house was about that of the operation of a large building air conditioner, while the noise inside the turbine house was extremely loud. The system seemed well engineered and to be performing as desired.

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V. Grinding

SEVERAL GRINDING OPERATIONS were observed. The advantages of grinding are a volume reduction and a reduction or elimination of vector and nuisance problems that are associated with tipping operations not using cover material. The operations observed were new, the oldest having been in operation for about two years.

The ballistic separation principle resulted in the Gondard mill * being the predominate equipment. The mills without ballistic separation generally would require some refuse preprocessing that increases both capital and operating costs. It was alarming to see some of the objects that were removed before or during the grinding operation. It was not uncommon to find U.S. Army howitzer projectiles on display in plant showcases. To date, this type of "solid waste" has not destroyed any installations or maimed operating personnel.

The Gondard mill uses a 140-hp motor to drive a single rotor, having 4 rows of 12 hammers, at a speed of about 1,000 rpm. Refuse is fed into the mill at a variable distance above the rotor, and as the material falls on the rotor, hard, resilient and heavy objects are propelled into a vertical trajectory of about 20 feet to a point where a deflection plate directs the material into a storage compartment. Soft, inelastic material is beaten through the mill grate by the rotor.

Experience has found that the refuse moisture content affects the ability to grind the material. If the refuse is too wet, it can plug the rotor and stop the operation; while if the material is too dry, the mill production is reduced because the material cannot pass through the grate. At one installation, a fire hose was used to wet the material as required. Nylon stockings were found to be difficult to grind in all mills. The stockings would wrap about the rotor and eventually would have to be cut away. It was found that about 600 tons of refuse could be processed before the hammers would have to be reversed or replaced. There was a shortage of operational cost data, but the indications were that the grinding costs were between those for controlled tipping and incineration or composting (about $2.50 to $3.00 per ton). It was interesting to find that no reliable data or reports were available documenting the actual volume reduction achieved by the grinding–tipping process. It would seem desirable to have such information before a large investment was made in the necessary equipment. Also, since the operations are new, no data are available as to expected settling rates of this type of fill material.

At some operations local farmers would obtain the ground refuse and apply it to their fields; however, this was a very small outlet for disposal of material. The normal procedure was to discharge the rejects of the mill into the bottom of the truck or wagon and finish filling the vehicle with ground refuse. On the fill area the material would be spread evenly or dumped in piles, with the final spreading and compacting being produced by the vehicle traffic on the site. No cover material was used.

It was reported and observed that vectors and odors were not a problem at the tipping sites for ground refuse. The hypothesis is that these problems are avoided by the lack of large void spaces in the ground material and the enormous dilution of the small amount of garbage by the mass of other material. The operation did, however, seem to

* Mention of a commercial system does not imply endorsement by the U.S. Public Health Service.

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produce a potential water pollution problem. While the sites were developed to divert accumulated rainfall or upstream runoff around or away from the tipping area, the direct rainfall was absorbed by the fill. At some sites, a dark, foul-smelling seepage was noted standing at the toe of the slopes of the tipped material. The leachate not only poses a water pollution problem but also provides a breeding area for mosquitoes.

It is interesting to consider, especially in relation to grinding in composting operations, the reports that grinding accelerates decomposition by providing an increased surface area for bacterial action; the basic premise of this theory is that the initial material is a solid mass, which refuse certainly is not. Another contradictory statement often made is that refuse makes a good sponge for retaining water. The sponge action is a result of a large amount of void space and available surface area. Considering these two statements and reflecting on operations observed, it would appear that grinding derives its advantage primarily by producing a homogeneous mass, and secondarily by increasing the surface area of the mass. It would be difficult, however, to achieve one condition without the other. Thus, it would be interesting to prepare sets of duplicate observation windrows: one would be mixed with sewage sludge, and the other would not. The sets would be prepared as follows: (1) raw material only; (2) material ground by a grinder; (3) material ground by a rasp; (4) material prepared by the Dano-drum principle. Time, temperature, moisture, and other desired analyses would be monitored as the material decomposed. The data produced could be useful in adjusting or revising compost plant operations.

Another interesting area of study would be the self-grinding action of refuse in a Dano drum. The material produced by the drum is comparable to that produced by a rasp or grinder. While the physical size and capital costs of a Dano drum would be greater than that for a grinder, the operating and maintenance costs would be considerably less. It would be interesting to study and compare the benefits, costs, and problems of a volume reduction operation using a grinder versus a similar operation using the Dano-drum technique.

VI. Composting

WHILE COMPOSTING is not the universal answer to solid waste management, it does have a place despite the possibility that this place will not become well established in the United States for many more years. There are a variety of uses for compost, but in general its primary use is to supply humus to the soil; and, as yet, humus cannot be artificially produced.

The German farmer has recognized the need to maintain the marginal organic content of his soil by operating a generalized agricultural system that resulted in materials moving from the soil to crops to animals and back to the soil. The efficiency of the system was such that there was a need to supplement the organic content of the soil by a source outside the system. Thus it was found that compost could produce results that were comparable to the results obtained by commercial fertilizers applied to mineral-deficient soils. The comparable results created some confusion as to the role of compost in the soil, but studies have now shown that compost is beneficial to the soil as a source of humus and not of minerals. There is some indication that the reformation now occurring in German agriculture may result in an increasing demand for a ready source of humus as the farms become more mechanized and livestock production becomes a specialized industry.

In the United States the vast land areas available per capita have resulted in single-use or low-level utilization of the land resources. As a result, the soils are considered young and fertile although suffering from poor management in many areas. If the future of the United States is close to what is predicted, the day will possibly come when a greatly decreased land area per capita will require the preservation of our lands for intensive agricultural production by transforming municipal wastes into compost or humus for the soil.

Equipment

Storage Pit. Since composting plants receive only the domestic and some small part of the commercial refuse from a community, we can understand that these plants generally have a small intake of material, ranging from 40 to 200 tons per day. Thus, the storage bunkers (pits) are designed to receive and hold approximately four collection-vehicle loads of refuse. The storage capacity is adequate to maintain plant operations, but when an operational breakdown occurs, an immediate and readily convenient alternate disposal system has to be available. Most of the bunkers are of a trapezoidic design with the two side walls sloping to a conveyor belt along the bunker bottom. The sloping walls help move the refuse onto the conveyor belt but create a problem by allowing the material to bridge-over the conveyor belt. It can be a very difficult job to break this bridge. The best solution to the problem in existing installations has been to construct a vertical falsewall along one side producing one straight and one sloped side. On new installations, a wider conveyor bottom would be recommended (conveyors 6 feet wide or more); however, none of the European installations visited had such wide conveyor bottoms. The Joint U.S. Public Health Service–Tennessee Valley Authority composting plant at Johnson City, Tennessee, uses a wide conveyor, which may be an effective solution to the problem. Most of the installations on the Continent had dust control equipment for the bunker area, but it was either not used, broken, or considered ineffective in operation. In plants where the storage bunker was too small, refuse would be discharged on the ramp and pushed in by a tractor as the bunker was emptied. Gen-

eral design called for a steel conveyor belt at the bottom of the bunker to feed a rubber conveyor belt that moved the refuse to the next processing stage.

Refuse Preparation. As the refuse moved from the storage bunker to the first processing step, some salvage and sorting operations were performed. Most of the plants were doing away with picking or sorting because of increasing labor costs and the small income from salvage. In general, the picking operation was inefficient and greater benefits could have been obtained by better education of the collection crews and the residents. Pickers removed rocks, tires, large pieces of iron, bottles, large sheets of plastic, and other materials considered undesirable for composting. No paper salvage was performed, and in general, the emphasis seemed to be on plastic removal rather than glass. Salvaged wine bottles are still a source of income, but the thrifty European, the increasing use of plastics, and the one-way bottle make bottle salvaging a negligible source of plant income. The nonsalvageable materials removed were placed in large portable containers for transport to the landfill or incinerator.

An over-band magnet, a drum-head magnet, or both, were standard equipment in all compost plants visited. The drum-head magnet is simply an electromagnetic roller at the end of the conveyor belt. The magnetic field places the ferrous material in a different trajectory than the other materials leaving the belt. The over-band magnet is an electromagnet directly over the conveyor belt. An endless belt positioned between the refuse and the magnet sweeps the material out of the magnetic field into a storage container. For greater efficiency two or more magnets might be located at different stations in the process. The iron removed was baled for storage and sale. German scrap iron suffers the same low price as U.S. scrap and was sold for whatever price it would bring, or else given away in exchange for the removal.

Processing: Grinders. Following intake, the refuse could be processed by grinding, rasping, or the Dano drum, depending on the composting system being used. If grinding is used, commercial grinders are supplied by the Buhler Company (double- or single-rotor grinders), the Hazamag Company (double-rotor grinder), or the Gondard Company. Gondard grinders are coming into greater use. The Gondard grinder was discussed previously, but it is worth repeating that the ballistic separation action by this mill actually provides a mechanical sorting or removal of much of the noncompostable material. The Hazamag grinder uses a high-speed double rotor with swinging arms made of flat steel. The Buhler single-rotor grinder uses flat steel arms equipped with a pivoting sledge-hammer-type head at the end. In either grinder, after some wear, the grinding surface can be reversed for additional use. The double-rotor Hazamag and the single-rotor Buhler mill are used for primary grinding; the double-rotor Buhler is generally used for secondary grinding.

As is standard practice for as much European equipment as possible, the grinders are powered by electric motors. It was noted that both grinders were considerably overpowered, but the Buhler mill seemed to be equipped with more excess power than the Hazamag. The excess power is required for starting and for overcoming slugs of material, or materials difficult to grind. Hazamag seemed to be relying on the inertia and grinding action of the double rotor to overcome the hard spots. In addition, the Hazamag mill was more heavily constructed than the Buhler. In the double-rotor Buhler mill used for secondary grinding, the two rotors turn at different speeds, and it was reported that the hammers of the faster rotor had about one-third the life of the slower rotor hammers.

All the grinders are very noisy in operation. None of the mills could grind nylon, especially nylon stockings. The stockings would sometimes accumulate on the rotor until they had to be slashed or burned away with a torch.

Processing: Rasp. Developed by the Vuilafvoer Maatschappij (VAM) firm, the rasp is marketed by the Dorr–Oliver Company. It is a vertical cylinder with a diameter of 15 feet and a total height of 7 feet, containing both a grinding floor and a discharge floor. The grinding floor is formed

from wedge-shaped sections with alternate sections being constructed with round holes (from about 0.5-inch to 1.5-inch diameters) or with 0.5-inch steel pins projecting from the section. The pins also extend part way up the wall all around the inside. There are eight heavy hinged arms that can rotate at various speeds up to 25 rpm. The arms move the material over the floor that serves to alternately screen and rasp the material. The arms can lift up over ungrindable material until such time as a trap door can be opened and the rejects swept out the door by the arms. The material passing through the grinding floor falls on the discharge floor and is moved out a discharge opening by a rotating arm attached to the center spindle. Compared to a grinder, the rasp is physically larger, requires about one-fourth the power, is somewhat quieter in operation, requires less maintenance, and has a higher first cost. The grinding and rasp system of composting appears to be quite competitive in the open market.

Processing: Dano Drum. The Dano drum, usually 9 to 12 feet in diameter and 60 feet or more in length, is rotated at a speed of about 1 rpm during the working day and at about ¼ to ½ rpm at night. The raw refuse is usually given magnetic separation before being discharged into the drum, where a slight inclination of the drum requires about 2 to 5 days for the material to pass through the drum, detention time being a direct function of the speed of rotation. The drum is operated half full, and the slow rotation provides aeration and the self-grinding action that is effective in the reduction of the raw refuse. When the material reaches the end of the drum, a short section of 1.5-inch-diameter screen is used to remove large pieces of reject material. The rejects are periodically discharged from the drum via a trap door in the screen. A characteristic of the drum compost is the presence of small balls of paper. There is some thought that the small, moist, porous ball provides a better microbiological environment than the material produced by a rasp or grinder. Compared to a grinder, the drum has the same advantages as the rasp.

A satisfactory aeration system has not yet been designed for the drum, and, as a result, many operations have been known to have serious odor problems. A recent solution developed for the odor problem has been the use of underground tile fields. The hot, odorous gases are drawn from the drum and forced into a perforated tile distribution network covered by about a meter of soil or compost. The cover material does an excellent job of removing the odors, and the technique is reported to enjoy wide success. When compost is used for the filtering cover material, the hot rising gases create a very nice hotbed, and the compost meisters enjoy performing small-scale growing experiments to demonstrate what their product can do.

Curing

A common method for providing compost curing is the compost windrow. With the practice so widespread, it is noteworthy that no efficient and effective equipment for windrow turning is yet on the market. Windrow turning is accomplished by the use of an end-loader and some type of elevating conveyor that piles the material in the triangle-shaped windrow. The height of the windrows is a function of the amount of compost produced and the storage area available.

At the June 1967 INTAPUC Conference, a model and diagram of a windrow turning machine was on display. The machine looked like a self-propelled stern wheel from a river boat. The wheel was supported by rails on concrete walls on each side of the windrow. As the wheel moved against the windrow, the paddle or cups elevated the compost to an overhead position where it then fell onto a conveyor constructed in the center of the wheel. The conveyor moved the material to the new windrow position. The machine is simple enough and appeared to have the capacity that would be required, but would have the disadvantages of an inability to shred the compost and to clean all of the windrow from the ground. Only one machine of this kind is reported to have been built and it is operating in the Bahama Islands.

No single test has been developed for establishing the frequency of windrow turning. The frequency is usually established by the following variables: the windrow

temperature as measured by a thermometer placed in the windrow, windrow or compost odor, and moisture content as evaluated by the compost meister's nose, sense of touch, and experience. Until effective and reliable test procedures are developed, composting, like brewing, will remain an art dependent on the compost meister to determine how much moisture to add to the raw refuse or compost windrow, the turning frequency for the windrow, and when the compost is ready for sale. This reliance on the compost meister has developed a fraternity of these men, and they circulate from plant to plant as the opportunities develop. A good meister seems to be someone with the ability to work with people, who doesn't mind being in the "garbage business," and is willing to serve time as an apprentice.

Preparation for Sale

At most composting operations visited, when the compost is judged to be finished, it will be screened once before loading. In some operations a final grinding will precede the screening in order to provide an evenly blended and uniform texture of material. Since glass is one of the most objectionable materials in compost, must effort is directed toward its removal. In general the machines used are one of three types. Ballistic separation is one of the most common principles used for glass and other hard particle removal. The first type, known as the ballistic separator, is the largest machine. Compost falling into one end of the machine strikes a high-speed horizontal rotor. The rotor paddles are often short railroad tracks. The paddles or impellers strike the compost and propel it in a horizontal or slightly upward trajectory. Hard, dense, and resilient particles will obtain a high speed and long trajectory, while the soft, light and inelastic particles travel only a short distance. The trajectory paths are confined in a horizontal enclosure, the length and partitioning of which can be adjusted according to the need. The second machine, the secator, is probably the most common device used, mainly because it is cheap and mechanically reliable. Compost falling from the end of a conveyor strikes a shield or bounce plate that directs the material vertically downward onto a revolving drum. The strike plate may direct the material onto the top center of the drum or slightly off center in the direction opposite that of the drum rotation. The heavy and resilient particles will bounce off the drum into a collection bin, while the light and inelastic materials are carried on the drum under the strike plate and into the storage area. The speed of the drum and the position of the strike plate are set in accordance with operating experience. A third machine type used is the inclined plate conveyor. Compost falls onto a steel plate conveyor that moves at an angle upward against the falling compost. Heavy and resilient particles bounce down and off the conveyor while the lighter material is carried upward. This method seems to be the least satisfactory of the three.

Another system observed was a vibrating conveyor belt. The heavier particles and glass would settle downward through the material to the belt. Near the end of the belt a scraper was set and could be moved up or down to remove the upper material from the belt, thus literally scraping the compost from the glass and other materials.

In general, any of these systems alone would be considered satisfactory. For improved quality the compost would sometimes be exposed to two or more of the preceding systems, or the same system twice. This, of course, introduced additional expense. The problem with this equipment is that greater glass removal results in considerable loss of compost and an operational balance between a maximum amount of glass removal and a minimum amount of compost rejection must be attempted.

Screening or sieving of compost is universal at composting plants in order to provide a gradation of the final product. There is, of course, a direct relationship between the amount of screening of the compost and the final cost. Most of the screens were the vibrating type, with a few plants using small drum-type screens. The screening operation was one point in the system where the operator could have a direct influence on the amount of compost produced. The screen openings could be changed to pro-

duce compost in accordance with the greatest sales demands. In the situation where there was no market demand and large stockpiles of material were unwanted, the screen size was sometimes drastically reduced; this greatly increased the reject material and cost per ton of compost produced, although to the untrained eye the plant operation appeared normal.

An experimental sieve for glass removal is being tested. The sieve is an adaptation of a coal sieve that operates on the counter-flow principle. The compost enters the top and falls onto a fine mesh, inclined, vibrating screen. Air, blown at high velocities upward through the screen, suspends the compost a short distance above the screen while at the same time moving the material up the slope of the screen, and eventually out of the machine. The heavier particles remain on the screen and are moved downward and off. Initial tests indicate that the machine works satisfactorily except that some amounts of the heavier compost are removed with the rejects. This may be solved with some modification of the machine or additional processing equipment.

The use of a cross-flow air current for large particle removal was also observed. The air current was directed across the compost falling from a conveyor. The installation did seem effective in removing wine corks, bottle caps, some plastic, and bits and pieces of other material, but the effectiveness is directly related to the preceding operations.

Production Costs

The most frequent questions asked at a composting plant always seem to be how much does it cost to produce the compost, and what is the income from the sales? At most plants these data seem readily available, and the computation (expenses less income) to arrive at the unnecessary operational subsidy seems easy. It usually is not. To attempt to relate economic data from one operation or plant to the same type of plant in a different area, or to a different type of plant, presents an even greater problem. The confusion is compounded when the different economies of two countries enter the picture. Among the many factors that create confusion in economic comparisons are types of refuse received, economics of the area surrounding the plant, plant age, plant mechanization, labor costs, salvage operations, remoteness of plant, and marketability of the compost. The reporting of operational cost data may be confused by the inclusion or exclusion of such things as capital costs, income from salvage, ancillary equipment utilized in the process, taxation or organizational support funds, and so on. Most of the plant operators recognize this problem but for various reasons have no desire to correct the situation. Most operators, however, work toward the goal of keeping the operational subsidy at the minimum level.

It was observed that most of the compost plants were located adjacent to the sewage treatment plants. The sewage sludge was recognized as useful in the composting process, and composting was considered a good method for sludge disposal. The cost accounting system usually included the expense of the equipment needed to transport and incorporate the sludge with the refuse but seldom recognized, by means of charges to the sewage treatment plant or something similar, the benefits of using composting for sludge disposal. The economy of composting could present a different picture if the expense for an alternate means of sewage sludge disposal were recognized. It might be assumed, in general, that if it is necessary to compare economic data for composting operations, an acceptable method of standardized accounting must be developed and utilized.

In most of the operations the "expenses" exceeded the "income," but the necessary subsidy was justified as a reasonable expense for the solution of the solid waste problem. When questioned why composting was the system used, some operators sooner or later admitted that a high-powered salesman had influenced the judgment of the local political body. This is not an uncommon problem. The surprising element was that even though the system didn't prove profitable, as long as the plant subsidy was kept low, the operation was considered acceptable. In most cases composting was justified on the basis

that incineration capital costs were too great, that there was a lack of room for tipping, or that the watershed laws forbade the deposition of any type of raw refuse on the ground. The law, however, was unclear on the difference between "raw" and "treated" refuse. Some serious questions might be raised about a law that forbids depositing "raw" refuse but fails to establish standards for acceptable residues that are deposited on the ground. There are no standards or quality control regulations established for compost produced unless the compost is mistakenly marketed as fertilizer. There are definite quality control standards for fertilizer production.

Compost Sales

Present technology is such that there is no problem connected with producing compost; the problem is what to do after the compost is produced. One of the most effective organizations for the utilization of compost is Vuilafvoer Maatschappij (VAM) of Amsterdam, Holland. One of the largest stockholders in the company is the Dutch government. The company has three major sections: technique, agriculture research, and sales; the operation of one section directly affects the other sections.

The history of VAM illustrates the evolution that has taken place in composting. VAM's first plant was built at Wijster in 1932 when there was a large demand for coarse, low-quality compost to use in land reclamation. At that time about 80 percent of the plant's production went to the land reclamation companies. By 1940, 90 percent of the plant's compost went to farms and only 10 percent to the reclamation companies. This drastic change resulted from the fact that during World War II commercial fertilizers were almost impossible to obtain, and it was necessary to utilize compost to maintain much-needed crop production. The movement to utilize compost carried through to the middle 1950's, and by then the widespread use of compost had resulted in the recognition of several new uses. Cattle were found to prefer grazing on pasture that had been covered with compost rather than stable manure; mixing compost with farm manure increased the organic content of soil; compost could be used as bedding material for chickens and pigs; it was found that compost was effective in curing anemia in pigs. These new uses, of course, increased the demand for compost. In the 20 years between the middle of the 1930's to the 1950's only 1 composting plant was in operation, but since then a total of 15 additional plants have begun to produce compost.

During the 1950's vegetable growing, flower cultivation under glass, and flower bulb cultivation became a large horticultural industry in Holland. This new industry had interesting effects on compost production. A finer quality product was required and the processing of the compost became more complex and expensive. This requirement and ability to produce a finer quality product opened up a new market, a market for what is known as "refuse heating manure"—freshly ground refuse devoid of any sharp particles. This is in great demand by greenhouses. The essential feature of the material is the large amount of heat produced during the decomposition of the organic matter. It is difficult to try to match the supply-and-demand aspects of the product because of the large seasonal demand and the need for the material to be fresh.

Flower bulb cultivation along the sandy North Sea coast created a big compost market when it was found that the use of hand-placed reeds and straw could be replaced by mechanized application of compost. The compost resulted in labor savings and, in addition, had the benefit that it could be left and worked into the soil to become additional organic matter. The ever-increasing population density and demand for recreation areas and parks have created a market for a peat-compost mixture. The peat compost in a 1:1 mixture is said to make the land ready for cultivation quicker and to give the plantings a faster start.

Finally, the changing economy of Holland is resulting in more leisure hours for the city dwellers: hours spent growing flowers in window boxes or on small plots of land. It is more agreeable to apply the compost to the soil than to use animal manures, as there is no relationship between the "power" of

a material and its odor. Thus, while most compost is sold in bulk, there is an increasing demand for small quantities in attractively packaged bags. It is interesting to note that while the compost meister curses plastic as one of the biggest problems in producing quality compost, the sales people find it the most attractive way to market the product.

From the standpoint of total sales, horticultural and recreational uses rank at top, while general agriculture is near the bottom. As a result of the above, the sales demands are met by compost of one of the following classes: (1) horticulture quality; (2) superquality; (3) peat compost; and (4) town refuse heating manure.

The VAM was established to develop and maintain a market for compost. The government is a strong partner in this organization because it recognized that the proper sale of compost provides a solution to municipal manure (refuse and sewage sludge) disposal problems, as well as maintaining the basic fertility of its limited agricultural land. From its long experience, the VAM company sets forth the following points as being necessary for continued compost sales: (1) a good outlet in the neighborhood of compost producing plants; (2) absence of competitive products such as farm manure, heating manure, etc., unless they have long supply distance; (3) cooperation by a large and well-stocked government information center; (4) the production of exclusive quality products that can be guaranteed completely; (5) favorable trading results with the buyers and no government restrictions; (6) very dry years when crops have had bad yields or died early because of lack of organic matter; (7) the importance of marketing a product with a trademark.

In conclusion, VAM does not hesitate to state that the production of compost is not a money-making proposition. The government is, of course, providing support for the organization, but the amount of the support is undefinable. The important fact is that the compost is sold. Several other countries are faced with problems similar to those in Holland, and some have the federal government involved; yet none has a sales group comparable to VAM and none enjoys the success in compost utilization that Holland does.

Special Systems

A composting system can be considered to have two parts; one part is for the preparation of the material and the other is for providing the required biological environment. Most of the present composting systems can be placed in one of four categories: (1) composting in fermentation cells with prior crushing of the refuse, followed by windrow curing; (2) composting in fermentation cells, followed by windrow curing; (3) composting in windrows without prior preparation, followed by compost product preparation; (4) composting in windrows with prior treatment of refuse without subsequent treatment of compost.

The following is a discussion of several special composting operations observed. While the systems presented are unique and generally the only operations of the kind in the world, the system components still fit the above categories.

Van Maanen System. The operation, first established in 1932, could be nicknamed the "open-dump composter." The majority of the refuse received is railhauled from Den Haag, Holland, about 175 kilometers to the composting plant at Wijster, Holland. The rail cars simply discharge the refuse onto the ground from rail spurs built on viaducts. Immediately after discharge, water sprinkling systems are operated to moisten the refuse. The operations are scheduled to provide up to 7 months' storage in the windrow if possible. After the desired curing time, the compost is transferred via gantry cranes and an endless train of mining cars to the processing building. The material brought to the building is first subjected to a thorough screening by successively coarser screens. The fine material first removed by the screen and given a magnetic separation is nearly free of glass and other undesirable items and makes the best quality compost produced. The material removed by the coarse screens is treated by magnetic separation, then either by a roller crusher or a hammermill. This lower grade compost can then be further re-

fined by ballistic separation and stockpiled for sale. Rejects are used to raise the level of the property adjacent to the windrow area.

The operation is well isolated from nearby farms. As would be expected there are vector and odor problems and a potential groundwater pollution problem connected with the operation. The Dutch government uses the 60-acre site as an experimental laboratory for evaluating vector control programs. Odors are a problem and efforts to use chemical masking agents have not been successful. An underdrain system designed to collect the leachate has been destroyed by corrosion, and some work is now being done to develop a new collection system and provide some measure of treatment for the water collected. A barge canal near the site was used to transport some of the compost to market, but trucks have now replaced the barges. It was reported that the fish in the canal were used as biological monitors for water pollution problems. This may be true, of course, provided that there *are* fish in the canal near the plant and that they are still sensitive to pollution. This is undoubtedly the lowest cost composting system in operation, but not necessarily the most desirable.

Baden-Baden System. The system was developed and is used at the city of Baden-Baden, Germany. It might be nicknamed the "modified tip composter." While being somewhat similar to the Van Maanen system, the operation is on a much smaller scale and provides better environmental control. Refuse is discharged from the collection vehicles into a small storage bunker, then lifted by crane to an overhead receiving hopper. The hopper feeds a rotating drum that was formerly used to screen out ashes but now serves as a flow equalizer for a sorting conveyor where magnetic separation and some hand-picking is performed. The refuse passes from the conveyor into a second drum and is mixed with sewage sludge (from sludge drying beds) until a 50- to 60-percent moisture content is developed, and then the material is discharged into a truck or wagon for transport to the windrow area.

The windrows are constructed on two lines of large-diameter, perforated concrete pipe. In former times air was blown into the pipes and out through the windrow, but odors became a very serious problem. The odor problem has been corrected by drawing air into the pipes through the windrow; the air drawn in is used as the air supply in the bulky waste burner on the site. Water is applied to the windrows and they are turned if necessary. Water pollution problems are handled by discharging drainage into storm drains or to the surrounding marshy area. After an appropriate period of curing, the compost is trucked to the plant, ground, and sieved for sale. The primary purpose of the plant is reported to be the satisfactory disposal of sewage sludge and not the production of compost. The compost that is not sold is used to raise the level of an adjacent marsh.

Caspari–Meyer Brikollare System. This process could be nicknamed the "cookie-cutter composter." The Brikollare system, while being the latest thing in composting, is also probably one of the more highly mechanized and expensive systems developed. The system actually replaces windrow curing with a "block" or "controlled" environment curing.

Refuse delivered to the plant is processed by magnetic separation and some hand sorting before discharge into a Dorr–Oliver rasp. After the rasp, the material is again processed by magnetic separation and ballistic separation. The material is then transferred via conveyor to the "brick" machine. Raw sludge, dewatered by a vacuum filter, is conveyed to a pug mill blending tank where three parts refuse and one part sludge is blended to produce a mixture with about 50 to 60 percent moisture content. After blending, the material is conveyed to a holding or surge tank for the bricking machine. By an elaborate and complex mechanical system, a measured quantity of the material is placed in a mold, vibrated for compaction, extruded from the mold, and stacked on a wooden pallet. The resulting brick, measuring about 15 x 15 x 20 centimeters, has the appearance of dark, raw papier-mâche. A half-moon slot parallel to the long axis, runs along the middle of the bottom of the brick.

When the pallet if full, a fork lift is used to transport the material to the curing shed. While the bricks are stored for about two weeks in the shed, temperatures of about 60° C are obtained and maintained, and large quantities of mold form. No odors were reported to be produced by the bricks.

The curing process was reported as follows. The group of stacked bricks provides a body of heat that maintains the temperature near the optimum for the desired biological activity. Much of the exterior surface of the brick is open to the atmosphere and aerobic decomposition takes place, while inside the brick, anaerobic activity takes place. As the products or byproducts of the anaerobic activity are transferred outward, they encounter the anaerobic-aerobic interface where they are transformed or modified into unobjectionable products. As the curing continues, the brick moisture moves outward and air moves inward and the microorganisms maintain the balance.

Experiments at the plant have shown that when the ground-up bricks are used as insulation material around the brick stockpiles, the stored bricks can still obtain air, and the stockpiles can be stored almost indefinitely. The bricks have the advantages of no odor in long-term storage and a reduction in the size of storage area needed. When the bricks are to be sold, they are passed through a hammermill and the compost is then screened to the desired grade. It is necessary to process only as many bricks as may be needed to produce the quantity of compost desired by the buyer. Although this system is expensive and is vulnerable to mechanical breakdowns, it provides excellent environmental control and produces a desirable product.

Humboldt. The Humboldt system is experimental and is now being developed and tested. The refuse is processed by magnetic separation while being conveyed from the storage bunker to a pug mill for shredding and mixing with sewage sludge. The pug mill has been modified to include shearing knives spaced at intervals along the twin rotors. The homogenized and shredded material discharged from the pug mill is placed in a tall, conical drum that looks very much like an elongated concrete mixer. The material moves downward by gravity and is discharged at the bottom by a scraper system. At the center of the drum are pipes used for the injection of air and moisture when necessary. Hopefully, the system will not require windrow curing and has the advantages of a minimum of mechanization, reduced power requirements, and a controlled environment. Nylon stockings present a problem in the pug mill because they do not shear and then become wrapped about the rotor and entangle pieces of refuse. The result is a huge ball of material that jams the machine. The process is patented and now operating on a pilot scale. When a full-scale plant might be constructed is unknown, and it is still too early to evaluate the potential application of this system.

Research

Soil Effects. Studies carried out to date indicate that compost has definite short- and long-term advantages when added to the soil for crop production. The exact mechanisms that create these benefits are unknown, but seem to be tied into the mysteries that still surround the material known as humus. Compost has been shown to increase the biological activity in the soil; this has been related to the fact that compost-produced crops experience less plant disease. The compost mineral analysis is well known and reveals that the material is definitely not a fertilizer; yet when applied to the soil, the compost produces a crop response that is very similar to that obtained with commercial fertilizer. Compost has been proven to provide a rapid start for plant growth and seems to be able to sustain the quick-start advantage through to the maturity of the plant. One hypothesis is that the dark color of the compost provides a better retention of radiant heat, and the radiant heat aids the growth process. Current experiments at Braunschweig, Germany, are testing this hypothesis.

Dr. Koepf at the Agricultural University at Stuttgart-Mohringen is undertaking studies on the relationship of nitrogen and the soil. The results of this work will certainly have an influence on compost utilization. Dr. Koepf and his colleagues have just completed

work on the background levels of nitrogen present in natural streams, and, in an effort to understand the source of the background levels, Dr. Koepf plans to study the fate of nitrogen applied to the soil. The studies may indicate how much nitrogen goes to the atmosphere, how much nitrogen enters the soil; and of the nitrogen that enters the soil, how much passes through the soil to the water, how much is utilized by plants and microorganisms, how much is retained by the soil, and what forms of nitrogen can best be utilized by the life systems of the soil.

It was noted that when immature compost was being sold, the compost meister usually advised the buyer not to use the material for at least two weeks. The meister had learned by experience that early application of the compost to soil results in adverse effects on crops because the microorganisms extracted nitrogen from the soil in order to complete their actions on the compost. A test for compost maturity in relation to nitrogen was observed. The test apparatus is also used for determining soil moisture *in situ* and consists of a pair of tongs with a wedge-shaped head that clamps about a special piece of porous paper. The instrument is inserted in the soil for a period of time, removed, and a measurement of the penetration of the moisture from the paper edge is referenced to a correlation curve to determine soil moisture. The same procedure is used in a compost sample with specially treated paper. The moisture content of the compost is measured as above, and then chemical additives are placed on the moist area. Color change determines absence or presence of nitrogen, with color intensity providing indication of the quantity. This test can be correlated with the compost maturity and used for guidance in future operations. Test accuracy was not guaranteed and its mechanism was not completely understood.

A test devised for compost utilization was observed and will be mentioned here even though out of context. Plant seedlings or seeds were placed in samples of compost of various ages. The sample with the youngest age that produced the desired plant response was judged to be the material mature enough for sale. The disadvantages of this test were: the large area needed to grow the seedlings; the necessity to keep repeating the entire process; and the need to wait for a period of about five days before results were known. Another study indirectly related to compost and soil effects involved earthworms. Two windrows of ground refuse were placed side-by-side, one as control, the other inoculated with earthworms. After two months it was observed that the control pile was anaerobic at the center and decomposing slowly while the inoculated windrow had decomposed rapidly into compost.

Erosion Control. The high population density of Germany requires maximum production from the agricultural land available, and sustained high-level productivity over a long period of time, so that soil losses must be minimized. One of the prominent German crops with a tremendous erosion potential is grapes grown on hillside vineyards. The grapevine growth is such that there is no ground cover, leaving the soil with a maximum exposure to the erosion-producing elements of nature. In the past, the hillsides were terraced for erosion control, but this is not an efficient utilization of the area available, and gradually the terraces have been replaced by the open mountainside. Both the German government and the Wine Growers Association have recognized the potential problem and have put forth money to determine what control techniques can be utilized.

Compost has been found to be a very effective material for erosion control, and the wine growers are probably the largest group using compost in Germany. Dr. Bosse, at the Bad Kreuznach compost plant, is employed by the Wine Growers Association to study the relationship of compost to erosion control and soil improvement in vineyards. About 90 percent of the plant production was being used on vineyards. On the hillsides where hand labor is necessary, the vineyard rows are planted 1.2 meters apart, while on the flatter areas the rows are 3.2 meters apart to allow the use of machinery. Studies have found that while the method of plowing has some influence, the application of 100 cubic meters of compost per hectare every

three years is effective in erosion control. Based on the fact that compost has been demonstrated to be an excellent material for erosion control, studies were in progress to determine the optimum amount and frequency of application needed to provide long-term benefits and maximum crop production by soil improvement with compost.

An interesting erosion control study has been made by German scientists. The question arose as to how much soil had been lost by erosion over the years. Hundreds of years ago when the land was first being cultivated, the hillside rocks were quite a nuisance. In clearing the fields the rocks were piled along boundary lines or at whatever distance a man could stagger with a large rock or throw a small one. The results of these efforts can be seen today as long rockpiles along the hill slopes. It was agreed that the earth under these piles should be at approximately the original elevation and, therefore, some of the windrows of stone were moved and precise measurements were made of the differences in elevation of the original and the present ground levels. The results indicate that approximately three inches of soil had been lost in several hundred years.

Pathogen Studies. Detailed studies have recently been completed in Germany on the subject of pathogen survival during the composting process. The principal investigator for these studies was Dr. D. Strauch, a doctor of veterinary medicine at the Justus-Liebig University Institute of Human Health Protection and Animal Health at Giessen, Germany. His primary interest was the epidemiologic study of the role of composting in relation to man, animals, and the soil. His studies, quite thorough, were performed on a variety of compost processes, and with a high degree of probability concluded that as long as proper temperatures, humidity, gas exchange, and detention times were maintained in the process, the end product contained no hazards for man or animals. His study procedures and findings have been published in German[7] and summarized in English.[8]

Dr. Strauch developed several interesting techniques during his studies. In one technique he used a Perlon plastic or cloth mesh bag that he named the "inoculation" bag. Two of these bags usually were used in his studies. Both bags were filled with 100 grams compost or ground refuse, and a hypodermic syringe or gelatin capsule was used to inoculate the bag with a known number of the organisms to be studied; a sealed ampule containing a known quantity of the same organism was placed in the other bag. The two sealed bags were then placed at a desired location in the compost windrow. The ampule provided data as to whether the pathogen destruction was a temperature function alone, while the bag, allowing free exchange of gases, nutrients, and most everything except the test organism, provided data on which microbiological interactions might be operating to destroy the pathogens. The results obtained were considered highly satisfactory. A different technique was required when the composing process included a fermentation cell such as the Dano drum. For this Dr. Strauch developed what he called his "sputniks," hollow, perforated metal spheres that were bolted together. He would place his inoculated bags in these spheres and expose the spheres to the composting process. In the first attempts to use the spheres in the Dano drum, it was found that they very quickly bounced through the drum. In order to closely simulate the movement of the material through the drum, the spheres were wired into place inside the drum and periodically the drum would be entered and the spheres transferred to a new position. Dr. Strauch felt the results obtained were quite reliable. Among the organisms tested by Dr. Strauch were *Bacillus anthrax, Salmonella enteritidis, Erysipelothrix rhusiopathise* and Psittaservirus.

Other studies have been carried on by other investigators, but the results obtained

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[7] STRAUCH, D. Veterinärhygienische Untersuchungen bei der Verwertung fester und flüssiger Siedlungsabfälle. Heft 18. In *Schriftenreihe aus dem Gebiete des offentlichen Gesundheitswesens.* Bundesministerium für Gesundheitswesen, Bad Godesburg, 1964.

[8] BANSE, H. J., and D. STRAUCH. The importance of pre-fermentation in composting. *Compost Science,* 6(3) :17–23, Autumn–Winter 1966.

were generally incomplete and nonconclusive. Research work on other aspects of composting had found that the optimum temperature for biological activity in composting is in the range of 40 to 50° C. With a humidity between 40 to 60 percent even the most resistant sporozoa are killed. It was found that antibiotic substances produced under the above conditions operated to control the pathogenic organisms.

In developing controls for the production of hygienic compost, two points must be kept in mind. The necessity for an optimum environment is pointed out above. The second point relates to how compost improves the soil. It is known that the processes occurring in compost enhance the soil biological activity, that needed plant micro- and macronutrients are produced, and that the compost finally becomes humus. The mysteries of humus are still unsolved. In order to produce the preceding benefits, compost must be placed on the soil as soon as possible. Therefore, as soon as the decomposition of the refuse in an optimum biological environment has satisfied the public health requirements, the process should be terminated in order that beneficial continuing actions can take place in the soil.

Reclamation. German studies are being made currently on the use of compost for the reclamation of marginal land. One scientist, Dr. H. Kick, is said to have done considerable work on the utilization of compost in the reclamation of land; however, it was not possible to contact Dr. Kick. From general discussion it was learned that other authorities believed that compost would be an excellent material to use for such activities. Obstacles to the use of compost would be determining: (1) who should pay for the production of the compost, its transportation, and its application; (2) how would the benefits and costs of the reclaimed land be distributed. It seems evident that there would have to be considerable government support for such operations, and at present, there are many other projects marked with high priorities for what German government funds might be available.

General Remarks

At the International Association of Public Cleansing (INTAPUC) conference there was an abundance of composting processes on display. The well-known composting systems were represented as well as several new processes that claimed to be long-awaited answers to problems of composting. It is suggested here that the old and new composting systems are developing in the wrong direction. The quality of compost needed to meet the market demand should be produced as simply and cheaply as possible. Some of the oldest and simplest installations visited produced a quality of compost equal to the product produced by modern, highly mechanized and very expensive systems. Mechanization is, of course, needed to offset increasing labor costs, but, on the other hand, increased mechanization usually has resulted in greater mechanical unreliability. Increased mechanization is also related to the fact that the principal marketing agents for composting systems are equipment or machinery companies that desire inclusion of as many of their products in one system as possible. If composting is to maintain a place as an acceptable technique in the solid waste utilization cycle, the process must be kept as simple as possible to avoid mechanical unreliability and excessive capital costs. Additionally, the composting operation needs access to an efficient sales department that can develop and promote new or existing products and markets.

VII. Sewage Sludge Disposal

OF THE INSTALLATIONS INSPECTED, a few had been developed especially for the disposal of sewage sludge. One very interesting operation was observed at St. Gallen, Switzerland. This was an experimental system designed to process the sludge from the Imhoff tanks of the sewage treatment plant. The system was designed for the use of a rotating drum hay-drier now available on the farm market. The sludge was pumped from a storage pit to a metering control that introduced the desired quantity into an auger conveyor. The auger provided some mixing of the sewage sludge with sawdust. The mixture (approximately 70 percent sawdust) passed from the auger through a mixing or agitating storage hopper and up an elevating conveyor into a rotating drum. Heat in the rotating drum was supplied by a gas burner placed at the drum inlet. The drum was designed with internal baffles arranged to pass the mixture the length of the drum three times before reaching the exit where the material was transferred by a blower into the top of a cyclone separator. The hot gases exited at the top of the cyclone while gravity moved the heavier particulate matter to the bottom where a short conveyor moved the material onto a vibrating sieve. The material that passed through the sieve was sacked for sale to a local fertilizer company while the sieve rejects, mostly sawdust, entered the auger at a point upstream from the sludge entry.

The principle of the system was that the sawdust served as a large blotter and absorbed most of the moisture of the sludge. When the mixture was passed into the drum, the heat provided was used to dry the sawdust and burn the sludge. In the cyclone, the fine particulate matter went out with the exit gases, but the inert particles of the sludge and a large proportion of the sawdust were recovered by the cyclone. In essence, the system attempted to provide a continuous recycling of the sawdust and seemed to be doing the job. A critical point was the control of the sieving operation. If too much material passed through the sieve, the necessary sawdust would be lost, and if too many rejects from the sieve were recycled, heat would be wasted on processing inert material. To learn that only a small part of the sawdust was lost by the system was surprising. The present operation presents an air pollution problem, and it was difficult to estimate if the necessary air pollution control devices would render the system economically unfeasible or not.

A different sludge processing system at Dübendorf, Switzerland, centers around what is known in the United States as the Nichols Oven. Refuse received in the storage pit was moved by a crane and conveyor belt into a primary grinder. After grinding, an auger conveyor mixed the refuse with raw sludge, and the mixture was discharged into the top of the Nichols Oven. As the mixture was transferred from one level of the tower to the next by means of slowly rotating arms, hot gases circulating through the tower first dried and then burned the material. The end product was a very fine, brown, powdery material. Temperature control could be provided by special waste-oil-burning nozzles or jets installed at the fifth or sixth level of the tower and exhaust gas vents at the top of the tower. The mechanical reliability of the system was an important consideration. The operator reported the system performed well but that there were frequent mechanical breakdowns.

A Nichols Oven-type system was used for sludge disposal at Stuttgart but no refuse was included. The Stuttgart system was reported to be sensitive to variations in the

moisture content of the sludge being burned, and it seemed possible that the addition of refuse might be one solution. It is planned to add additional levels to the drying area of the Stuttgart plant oven. While it is difficult to visualize the Dübendorf operation consuming large amounts of refuse, it could possibly be a sludge-refuse disposal system for a medium-size municipality to consider. The inclusion of the refuse would have the advantages of a more stable sludge disposal operation and the extension of the life of the landfill, but the disadvantage of the need for more equipment.

Lausanne, Switzerland, used the better-known method of the fluidized bed technique for sludge disposal. Thickened sewage sludge was taken from the storage tanks and dewatered in a combination hydraulic–vacuum filter press. The filter cake produced was transported into the burning tower where auxiliary fuel was used when necessary to sustain the process temperatures. Air, and at times the auxiliary fuel, was blown upward through a sand bed on the tower bottom. After entering the top of the tower to be dried, the sludge ignited and burned as it moved downward through the hot gases and flames. The system was equipped with an electrofilter and a waste-heat boiler to recover the heat content of the sludge in the form of steam or hot water.

It was noted that large amounts of material removed from the sewage channel by the bar screens were trucked to the municipal incinerator for disposal. Inquiries were made as to why the screenings couldn't be disposed of by the high temperatures of the sludge incinerator. It was reported that in working with the pilot-plant model of the system, efforts made to burn the screenings in the tower had not been successful. The problems resulted from large amounts of inert material in the screenings being deposited in the incinerator sand bed and eventually disrupting the movement of gas through the bed. There were no plans to investigate whether the full-scale operation would respond in a different manner than the pilot plant.

VIII. Incineration

WHEN ANALYZING most incineration plants, a general lack of data on operational economy is encountered. Incinerators are expensive to build, operate, and maintain, and it would seem desirable to have the economic components identified in order to evaluate expenses. In general, however, the desired data can only be obtained by a long, thorough analysis of operating and accounting records. Where the accounting system appears to provide the desired data, it is often found that the categories provided are poorly defined and overlap. The development and utilization of a standardized system for summarizing and reporting all operating and accounting data would be useful. Because of developing interest in waste-heat recovery, much is currently being written on the comparison of U.S.–European operational cost data. Most of these comparisons can, at best, be considered only as interesting. Cost data are most often equated on the basis of the existing monetary conversion ratio, which is undesirable because it does not correctly reflect the purchasing power of the system involved. For example, the present monetary conversion ratio is four German marks for one U.S. dollar (a 4:1 conversion ratio) yet it is generally stated by the Germans that the four marks have only one-half the purchasing power of the U.S. dollar.

Cost comparison is additionally complicated by fluctuating national economics. German authorities believe that the fluctuation of the German economy makes it undesirable to try to compare present-day economic data with that of the past. German doctoral dissertations that attempted to develop baselines for past and present comparisons or for the international comparisons have generally concluded that it is an extremely complicated task and that comparison of cost data between two countries is very uncertain.

The German financing of large solid waste management systems is little understood. Operational costs are paid for by a fee charged to the users of the system; when fees are inadequate to cover expenses, a government subsidy from general taxes is provided. While the construction costs of roads, schools, and so on, can be provided by the sale of low-interest bonds and taxes, solid waste disposal facilities seem excluded from the same procedure; the money required for the construction of a public solid waste facility has to be obtained on "the open market" in the same manner that a private company would build a similar facility.

In reflecting on existing solid waste management systems, amortizing the cost of a facility over a period of 20 years seems unrealistic, because it appears that most authorities continue to operate a facility long after it has become obsolete and the accounting system has evaluated the facility as fully depreciated or replaceable. Continued operation of an antiquated facility undoubtedly results from the fact that politically it is easier to provide operating funds than it is to get voter approval for a large bond issue to construct a new facility. In view of the rapid change in technology now being experienced, perhaps 10 years would be more realistic for amortization. The shorter time would place a greater financial burden on present users but would allow a faster system response to a changing situation. It is hoped that efforts will be directed to develop usable guidelines for finding the proper solution to financing of solid waste management systems.

Design of European solid waste management systems seems to be based on optimum design rather than the minimum cost prin-

ciple used in the United States. Based on the minimum cost principle, European facilities would be considered overdesigned, but the optimum principle dictates that the excess capacity (about 15 to 25%) is necessary to cope with fluctuations in refuse character, to provide for routine maintenance operations, and to balance with mechanical unreliability of the system. Most of the large European incineration plants have been built since 1964 and can be considered new plants. Because of shakedown problems experienced, many plant operators feel that 25 percent standby capacity is not enough, and it will be interesting to see if this attitude changes as the plant operations become established. It appeared that most of the operational problems had been produced by increased mechanization of the systems that created a large mechanical unreliability factor. This unreliability factor has grown large enough that high capital cost for standby equipment is forcing an effort to improve equipment.

Incinerator Equipment

Scales. Each incineration plant visited weighed all incoming and most of the outgoing material. At the older plants the scales were generally of the standard manual Fairbanks-Morse or Toledo design, whereas the new plants used an automatic reading and printing of the essential information on a weight ticket. Sometimes credit cards were used for large sources of incoming materials. In this arrangement each incoming vehicle carried a metal plate upon which was coded such information as name and address of company, tare weight of truck, truck number, truck capacity, and so on. The driver inserted the card into a reading console, and card information and load weight were stamped automatically on a weight ticket for incorporation into a monthly billing system.

Some of the weighing stations were equipped with an illuminated number board, the numbers corresponding to the numbers on the unloading bays. These were to be used to direct the drivers to the proper unloading bay. Unfortunately, the weighmaster was sometimes located where he could neither see the bays nor use the board, so that it was necessary to have a spotter to direct the unloading of the trucks.

Storage Pit. The incinerators' unloading areas were generally shielded by only a cantilevered canopy. Each unloading bay was equipped with a large door that could be closed to provide extra storage pit capacity and was usually only opened far enough to allow unloading of the trucks. Minimizing the storage pit opening aids the under pressure of the storage pit, which creates sufficient air velocity to carry and retain the dust in the storage pit.

It has been found by experience that a deflection chute will increase the effective volume of the pit that can be filled by the unloading trucks. Direct discharge into the pit results in material stacking against the near wall in a trapezoidal fill, with a steep slope and a long major side. The deflection chute provides a horizontal component to the trajectory of the material and moves the impact area toward the middle of the pit. The resulting filled area is a trapezoid with a decreased slope and a longer minor side. At the Issy plant in Paris, France, the deflection chute and bay door were combined in the form of a drum that revolved about 45°. When open, the face of the drum formed the chute into the storage pit; when closed, the drum face rotated upward to form part of the wall of the storage pit by closing the open area, while the outside of the drum sealed off the unloading bay. At Düsseldorf, refuse was discharged into a rectangular box, open on one side. A device built and operated like a ship's rudder moves back and forth through an angle of 180° to sweep the material from the box into the storage pit. Of the two devices, the drum might merit further consideration. European transfer vans, generally of the side-dumping design, are unloaded at an incinerator by means of a tunnel behind the storage pit backwall and deflection plates through the same wall.

Most plants operate seven days per week and thus require a storage pit capacity sufficient to continue operations through the weekend. At the large-capacity pits it has been found that refuse stored for two or three days is easier to incinerate. The storage period results in a more uniform moisture

content of the material, and some of the decomposition gases generated in the refuse could aid in the combustion process. The necessary storage capacity and detention time is provided by a wide pit and sometimes by the use of a dividing wall running the length of the pit. The refuse can be piled up for storage without the dividing wall, but the wall eliminates the danger of an avalanche of refuse falling and damaging equipment.

In the loading areas dust was controlled by the under pressure or slight negative pressure in the storage pit. This under pressure was produced by drawing the incinerator underfire air from the very top of the storage pit area. Locating the intakes as high in the pit area as possible produced the desired under pressure without the complications of the plugging of the intake by paper or plastic. In fact, the intakes were generally unscreened.

Sodium vapor lighting was used to illuminate the dusty storage pits as well as other dusty areas of the plants. The yellow light seemed more restful than fluorescent light, which is harshly reflected by the dust. It was also reported that the yellow light improved vision in the dusty area. The sodium light fixture is reported to have the disadvantage of a short life.

A bulky waste shear was usually built into an unloading bay at one end of the pit so that the material processed by the shear could be discharged directly into the pit. The shear was either a hydraulic ram or scissors designed to produce the desired size of material. Both devices seem to have some difficulty cutting rubber tires. Unburnables such as bedsprings, bicycles, and washing machines were separated by hand from the bulky waste and stored for removal.

Cranes. Standard design provided two bridge cranes and a third one available as a standby. Some facilities were designed to allow a disabled crane to be removed for repair. The cranes were the standard bridge-type, equipped with a polyp or orange-peel bucket, operated from a stationary cab positioned on the backwall of the storage pit. Small plants had one cab at the middle of the wall, while large plants had additional cabs at each end of the wall. The stationary cab seemed a better design than the usual traveling cab of U.S. design. The European stationary cab had advantages of no vibration, good visibility, air conditioning, better lighting, and easier access, all contributing to greater operator comfort. Power was supplied to the cranes by draped, covered control cables rather than bare, open wires. The cranes had a slower hoisting speed than U.S. design; the slower speed, however, resulted in better operational control and fewer collisions between the grapple and the walls.

A polyp or orange-peel grapple was standard design. The polyp has the advantages of a better digging action in refuse, and a polyp grapple equal in tare weight to a clamshell bucket will lift a larger volume with each hoist. The weak point of the polyp is the elbow in each section, and any failures usually occurred at some point in the elbow. Although the polyp is unable to compete with the clamshell bucket when it comes to cleaning the bottom of the pit, the operators feel that such a small portion of operating time is spent cleaning the pit that it is a very minor advantage for a clamshell. The cranes were equipped with strain-gages for direct reading and recording of the load being lifted ; thus, reliable data were available on furnace feeding or operating rates.

In some facilities special design features resulted in the crane operator being provided with a closed-circuit TV monitor in order to see operations out of his direct view. At one installation, for example, a cantilevered section of the storage pit allowed the crane to empty loads of bulky refuse and to load trucks with large, unburnable objects that had arrived in the storage pit. The TV monitor provided the operator with the additional visibility needed to safely maneuver his crane.

Charging Equipment. There was considerable variation in the methods of the furnace charging. The charging hopper might be set level with the floor, requiring a man to sweep the spilled material into the hopper; the hopper might be designed into the backwall, so that all spilled material fell back into the storage pit; or the metal hoppers that are common in U.S. design might be used. To feed the refuse into the charging

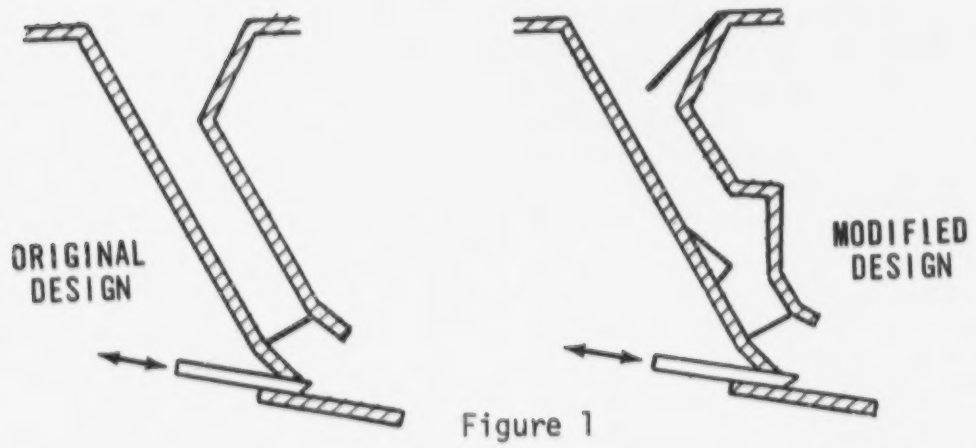

Figure 1

chute, some plants used a vibrating shaker. The shaker provided a more controlled method of feeding the chute and avoided compacted slugs of material in the chute. Shaker action was controlled by radiation sensors located near the bottom and top of the chute. The radiation sensors nicely avoided the kind of problems that electric eyes would encounter. It was noted that where the chute was charged directly by the crane, the large volume of material in the grapple required the operator to wait until the level of the material had moved far down in the chute. When the charge was placed in the chute, the outrushing displaced air created a tremendous dust movement that interfered with operating visibility.

Experiences with material avalanches or compacting and wedging in the chute have resulted in the placement of deflection plates in the chute, which seem to provide the desired feeding action (Figure 1).

Generally one of two mechanisms is used for moving the material from the chute into the furnace. One design is simply a hydraulic or chain-driven ram that moves slowly forward along the bottom of the chute forcing the material into the furnace. The completion of the forward stroke is followed by a fast action return of the ram. The other design is a hydraulically driven curved plate. As the curved plate moves slowly forward and down, the surface friction created by the weight of the chute material moves the refuse along with the plate. On the return stroke the weight of the covering material exceeds the surface friction and the charging plate moves back up under the material to begin the next cycle.

Grate Systems. In European incinerators as well as those in the United States, many types of grate systems are available. However, three systems are the best known and appear to produce comparable results when properly designed and constructed. These grates are the Von Roll (the reciprocating grate), the Martin (the reverse-action grate), and the VKW (the Düsseldorf or drum grate). The Von Roll grate has been built and used in the United States but the other two systems have not yet appeared on the North American Continent. The drum grate is a relative newcomer to the incineration field and is being used in several of the larger plants now under construction.

Since the Von Roll grate has been used in the United States, it is assumed that there is a general familiarity with the design. The Von Roll Company prefers to do the turnkey jobs (both the design and construction) for their plant, and in visiting their plants, it is interesting to see the evolution in their design; no two plants are the same. Most of the plants include features considered the latest available at the time of plant construction. The grate design presently being used has two interesting features. The first is the development of a refuse bed agitator known as the "moons," a series of quarter circles about 2 inches thick fixed to a shaft and evenly spaced across the grate system. When activated, either manually or by an automated sequence, a hydraulically driven rocker arm rotates the moons from a position nearly flush with the grate surface through a 90° angle that results in the quarter circle projecting from the grate. Al-

though the action was said to provide agitation of the bed and produce a better burnout of the material, a significant improvement in burnout was not observed. The second new feature is a reduction of the open area in the grate. In earlier designs the underfire air traveled directly upward through large openings in the grate bars; now, however, the design causes the underfire air to move upward between the grate runs and outward through the toe of each grate step. The current design has features that are quite similar to the Martin design. In Sweden it has been found that the use of 30 percent chromium in grate bar steel can extend the life of the grate; Von Roll grates are reported to contain 25 percent chromium and about 15 percent nickel.

The Martin grate has long been used to burn coal and has a fairly long history of use in refuse incineration. The system has been named "the reverse-action grate," because while most grate systems work to move refuse down the slope, the Martin grate pushes uphill against the movement of the refuse. The uphill action of the grate provides considerable agitation of the fuel bed and minimizes crater areas, formed by burnout of highly combustible material, that result in uneven air distribution through the bed. In addition, the upward action is said to push burning material under the new material and provide heat for drying and ignition both above and below the refuse bed. The system design eliminates the need for a separate drying grate and results in the combustion and burnout of the refuse in quite a short distance. The Martin grate is composed of a series of runs, each run being about 6 feet wide. For increased capacity additional runs are added, which results in a large capacity furnace, short but wide. Each run generally has 4 or 5 compartments for underfire air; thus, a large-capacity furnace, about 40 feet wide could have as many as 30 to 35 individual compartments to control the distribution of underfire air. This gives a great deal of flexibility in controlling the burning of the refuse bed. At present, pressure manometers are used to monitor underfire air distribution, but it might be desirable to instrument the underfire compartments more completely to provide more exact information on the amount of underfire air being supplied to each compartment.

The key feature of the Martin system is the large, highly-machined, hollow-finned, high-chrome alloy grate bars. The finned bottom is designed to cool the bar by circulating the underfire air over the bottom of the bar before being discharged upward between the bars into the fuel bed. The grate bars are machined to close tolerances to provide great resistance to the upward movement of the underfire air. The design concept is that the high-velocity air prevents riddlings from moving downward between the bars, and if the air can overcome the built-in resistance of the grate system, it is able to penetrate the fuel bed. Depth of the fuel bed is maintained at about 3 feet by a roller at the end of the grate.

The Martin grate has been criticized for its mechanical unreliability. In the early stages of its development, large, leaky, low-pressure hydraulic cylinders were used to provide lateral motion; however, it was soon found that a mechanical drive system was better. The unreliability of the present mechanical drive system results from use of electric motors, gear drives, and a driving arm to translate rotary motion into the lateral movement needed to move the grate. Technological development has produced a compact, high-pressure hydraulic cylinder that the company intends to use to operate the grates in future plants; it is indicated that the new hydraulic system might be used to replace the mechanical drive in some of the existing plants.

Although used in South America, the Martin grate has not been built in the United States because of the need for the machining of the grate bars. Either the construction of a factory to machine the bars or the shipping of machined bars to the United States would add enough additional cost to the first such plant that the company has been unsuccessful in competitive bidding. It is reported that the company has been doing well in Europe where it builds plants on the basis of a guaranteed performance contract.

The third grate system is known as the

Düsseldorf system because it was developed in experimental work in that city. The VKW Company produces the grate, which consists of a series of seven drums located in line on a slope of 30°. Each drum is about 5 feet (150 cm) in diameter by 10 feet (300 cm) in length and consists of short sections (about 1 foot in length) of heavy serrated grate bar fitted onto a structural steel skeleton or spider. Only about one-fifth of the drum surface is exposed to the fuel bed at once, allowing use of a lower quality steel in construction. Each drum has its own drive motor, gears, and underfire air compartment. The first and last two drums turn slower than the middle three to provide drying, combustion, and burnout zones.

Early designs had difficulties with refuse avalanches flowing from the charging chute to the residue hopper, but design modifications have eliminated that problem. Early systems also used six drums followed by a continuous grate for the burnout zone; however, it was found that the addition of the seventh drum could provide the desired effect without the continuous grate.

The rolling action of the drum produces an even fuel bed over the drum, and the transfer of the material from one drum to the next provides an agitation of the material in the transfer zone. A scraper or divider plate passes the material from one drum to the next and prevents material from traveling with the drum down into the wind box. Operators are quite satisfied with the performance of the system and report no problems with material wedging between the drums or the drum and the scraper blade.

Worth noting is the incinerator at Stuttgart because the plant has one furnace using the Martin grate and one using the drum grate. Such installations are quite rare. In routine operation one furnace is operated for eight weeks, then stopped for maintenance and repair while the second furnace is operated. The system has been operated for about two years now, and the indications are that the drum grate has greater mechanical reliability and the Martin grate (not equipped with new hydraulic drive system) produces less particulate matter and greater burnout of the residue.

Residue Hoppers. Many of the facilities visited used a quench tank system similar to that used in the United States. In this system residue falls directly into a large water-filled tank where a long chain conveyor moves the residue along the bottom of the tank, up an inclined plane for drainage, and into a waiting truck or storage pit. Disadvantages of the system are its need for a large quantity of water, its production of a high-moisture content in the residue, and its collection of floating grease and other materials on the water surface; a break in the chain, moreover, stops the entire operation and takes considerable time to repair.

The Martin Company modifies this system and places small individual tanks on hoppers under each furnace. A wide furnace might have three compartments. While a water-level control keeps the tank full of water, a hydraulic scraper pushes the residue up an incline out of the tank and onto a rubber conveyor belt. The scraping bar is connected to the charging chute so that when material is put into the furnace, residue is pushed out. Long rubber conveyor belts were common in most plants and used to transport the residue to the storage area. At one plant a short, sectioned rubber belt was used. The sections had cross bars that made the belt more like a flight conveyor and had the advantage that a damaged section of the belt could be quickly and easily removed for repair.

The Volund Company provides another type of quench tank. A large U-shaped trough constructed on a slight incline reaches completely across the width of the incinerator. Residue falls directly into the tank, and at preset intervals a large quantity of water is released into the upper end of the trough, flushing the residue into a storage tank. A screened and filtered intake is used to withdraw the water for recycling. The system does not seem to provide any important advantages and has the big disadvantage of requiring a large amount of water. It was reported that a general design value often used is that the total water consumption for an incinerator will be about 4 cubic meters per ton of refuse.

Residue Processing. Many plants in-

cluded equipment to process the incinerator residue for use in road subbases, path or trail construction, or as aggregate in concrete construction. First crushed by a roller or a hammermill, the residue is then passed under an electromagnet to remove the ferrous material to be baled and sold for scrap, and then screened according to the gradation required. Since there is considerable investment in the residue processing equipment, it would require a careful cost analysis to determine if the extra cost was justified. Such an analysis would need to consider extra capital cost and operating expense of the equipment, money received from product sales, savings in the reduction of material to be transported to the landfill, extended life of the landfill, and possible uses of material produced compared to uses of more expensive or even unobtainable materials.

Heat Recovery. Currently there is much ado about the "advanced" solid waste management techniques in Europe using refuse incineration heat to produce steam or some other readily usable form of energy. It was the observation of the writer that European practices are *not* an advanced technology, but rather, that the economic situation is such that a more expensive system for refuse disposal can be justified. The high population density and a high cost for an energy source provide a different environment for evaluating the recovery of energy from refuse incineration. As an example, the city of Munich is often cited. Munich is a long distance from the coal mines and transportation costs increase the price of coal in Munich nearly 50 percent above the price at the mine. Any procedure that can reduce or replace the amount of coal used is given careful review.

Population density is the big consideration. Present European population density has resulted in quite stringent air pollution laws, and the equipment needed to comply with the air pollution regulations operates more efficiently when combined with heat recovery operations. In Europe multiple dwellings and high-rise apartment complexes are the norm and individual homes are in the minority. Such population clusters can be most efficiently heated by central steam or hot water heat; thus, an area of high refuse production and a demand for a readily usable form of energy exist together. Operating experience has found that the income from the sale of steam to heating plants is greater than the income from the sale of steam to power companies. It is recommended, moreover, that electrical power production equipment not be included in an incineration facility because the electrical equipment results in increased capital costs, operating costs, personnel costs (a more highly skilled category of personnel must be added to the staff), maintenance problems, and a greater factor of mechanical unreliability for the system. Most operators prefer a system where they can produce as much steam as possible with the burning refuse, send the steam to a company that will use it, and receive treated boiler water in return.

General design values reported were: 1 to 1.5 pounds of steam are produced by 1 pound of refuse; the electrical consumption by an incinerator is about 40 kilowatts per ton of refuse; total water consumption is about 4 cubic meters per ton of refuse; auxiliary fuel costs can range up to 6 cents per ton (this value is not considered too reliable); and repair costs 2 percent annually of capital investment. Although it is agreed that residue quality cannot be accurately judged by eye, a visual examination does provide a crude form of evaluation. Visual examination of plant residue indicated that the operations that were controlled to produce the maximum amount of steam with the incinerator heat available produced a good quality residue. This is logical since the greater the burnout of the residue, the more calories released to be recovered as steam; thus, maximum steam production may be an indirect operational control for production of high quality residue.

In regard to the design of the heat-recovery boiler, plant operators pointed out that many authorities recognized and stated that a boiler operating with heat from the burning of refuse has to be of a different design than a boiler that uses heat from coal, oil, or gas; yet boiler manufacturers had not yet acknowledged this difference. Boiler

manufacturers often state that the source of heat is unimportant as long as there is a favorable ratio between the cost of the heat from the fuel and the temperature of the gas in contact with the heating surface. It was recommended that special effort be made to inform prospective refuse-burning boiler designers on the problems such boilers would be expected to cope with successfully.

All heat-recovery operations visited used water-cooled furnace walls. Economic considerations and boiler design requirements determined whether or not the water pipes would extend to the grate level or terminate 3 to 4 feet above; in the situations where the pipes were located close to the grate, a refractory material was used to shield the pipes from abrasion. In standard refractory wall design, adhesion of slag or cinders to the combustion chamber sidewalls is sometimes a serious problem. Experience has shown that this problem can be avoided by constructing water pipes the length of the furnace just above the grate and connecting these pipes to a boiler or to heat exchangers for preheating combustion air.

Corrosion and slagging is a prime consideration in incinerator boiler design and use. It has been suggested that European designs have avoided this, but it is not always pointed out that many of the major incinerators have only been in operation since 1964. It should also be noted that apparently the amount of plastic in European refuse is increasing each year and it is only now that there is enough of it to begin causing problems.

Combustion of polyvinyl chloride (PVC) is a major source of corrosion. The burning of PVC produces large quantities of soot, and at temperatures above 230°C, about 50 percent of the chloride is released as HCl. The soot readily absorbs the HCl, and if the soot adheres to a metal surface, serious corrosion problems result. Heat-recovery boilers are usually designed to produce steam with pressures between 14 and 72 atmospheres and temperatures between 160°C (dewpoint) and 430°C (melting point for chlorides). Since some corrosion is inevitable and the use of high pressures and high temperatures would require special equipment (increasing the capital cost of the facility) and would decrease the life of the convective surfaces, it is preferred to produce steam with temperatures of 180° to 250°C and pressures of 40 to 50 atmospheres.

Older designs kept each boiler pipe separate to expose the maximum convective surface. The present trend is to route the hot gases through a steel-tube box constructed from finned boiler pipes that are welded together. In the old design as well as the new one, it has been observed that the greatest corrosion problems seem to occur directly over the combustion zone and a parabolic pattern is usually developed on the pipes. The situation has been successfully corrected in some plants by providing additional air jets in the critical zone.

To reduce corrosion problems, the tube nests might be designed for straight-through gas flow rather than for use of the standard staggered design. This would reduce convective efficiency but would compensate by reducing the problems of surface clogging and by allowing the use of soot blowers. In addition, the tubes might have a wider spacing than the normal recommended spacing of two to three times the pipe diameter.

With refuse being such a widely varying fuel or heat source, incinerators must be designed for peak conditions, not averages. As a result, incinerator boilers have a low overall efficiency (steam production to calorific value of refuse) of about 60 to 75 percent as compared to the usual 90 to 95 percent efficiencies for conventional fuel boilers. Also related to efficiency is the availability factor (ratio between annual operation of an incinerator and its potential annual operation); this should be as close to 1 as possible; in practice, however, the mechanical reliability of a system produces a factor ranging from 0.5 to 0.9. The low factor results in the provision of reserve or standby capacity of 25 to 50 percent of the plant capacity as mentioned above.

It might be added that steam and electrical power production with incinerator heat are not considered to be profit-making operations. Refuse is a heterogeneous fuel and re-

quires more equipment and manpower for burning than conventional fuels. It was reported, in most situations, that for the production of the same amount of heat, it would be cheaper to burn a conventional fuel rather than refuse; however, when the extra costs are charged to the solid waste management system and the intangible benefits of conservation of resources, or resource management, and the protection of the environment are included in the benefit-costs determination, it may be a wise investment even should the operation require subsidizing.

Air Pollution Control. An important benefit of incinerator heat-recovery equipment is the cooling of the hot combustion gases. By being able to efficiently reduce gas temperatures from about 1,000° to 250°C before arrival at the air pollution control equipment, the size of the air pollution control devices can be considerably reduced. Problems have resulted in some systems where for monetary reasons the size of the pollution control devices was reduced below proper design size.

One of the more impressive features of European incinerators is the quality of the stack effluent. While some particulate matter is removed when the hot gases are forced to change direction in moving through the incinerator boiler, the greater portion was removed by an electrostatic precipitator. The electrofilter is standard equipment on all incinerators and is the only gas cleaning equipment used. Suspended particles passing through the electrofilter may include some charred paper, metallic particles, fiber, glass, carbonized organic substances, and so on. Collection of these particles in an electrofilter can be obtained only at low gas velocities because of the relatively high particulate conductivity. Gas velocities for electrofilters working with conventional fuels can range from 2 to 10 feet per second (fps), while for incinerator electrofilters with inlet temperatures of 250°C, velocities of 0.8 to 1.2 meters per second (2.6 to 3.9 fps) are recommended. With these design velocities, properly shaped electrodes, and an efficient filter cleaning system, the stack effluent should be able to comply with the most stringent codes. First attempts to design an electrofilter for an incinerator usually resulted in the need for a mechanical cleaning device following the electrofiltering, when efforts made to save money by reducing the size of the electrofilter resulted in the filter gas velocities being too high. Early designs also attempted to use a smooth discharge plate in the filter. Experience and tests have proven that a corrugated surface produces eddies or pockets beneficial in collecting and retaining incinerator gas particulate matter.

Fly ash collected by air pollution control equipment is usually transported to a storage area by water, an auger, or by a pneumatic system. Water transport is considered to be the least desirable method because it has the disadvantages of severe corrosion problems, the eventual necessity to separate the fly ash from the water, and increased plant water consumption. Pneumatic or auger transport systems seem to be equally popular from the design standpoint, although operators prefer the auger system. Plant operators reported that the pneumatic systems generally do not have sufficient capacity, and in addition, fly ash has a tendency to stick, bridge, or cake in the storage area above the transport system. The pneumatic system lacks a positive action that can loosen the caked material. The auger has the positive action with an inherent vibration that is useful for loosening the fly ash.

The electrofilter is followed by a tall stack. There was no evidence of any attempt to utilize a shorter stack. While effort is directed toward controlling the particulate emission, little is done to control the effluent gases. The tall stacks required by outdated air pollution laws are based on an empirical formula using selected dispersion coefficients.

Particulate emission is limited to 150 milligrams/Ncbm.[9] This is about 0.2 pound of particulates per 1,000 cubic feet of flue gas corrected to 12 percent/carbon dioxide, as compared to the U.S. standard of about 0.4 pound of particulates per 1,000 cubic feet of flue gas and corrected to 12 percent/carbon dioxide. Knowing that this stringent

[9] Ncbm = Normal cubic meter.

standard existed, it was quite interesting to oftentimes observe municipal incinerators producing a "clear" stack effluent alongside a large industrial complex with stacks emitting large clouds of multicolored material. There is considerable political lobbying to have the air pollution laws relaxed because they are reported to be causing economic hardships for industry, but this is not a satisfactory answer to why there is such a wide divergence in the enforcement of the existing air pollution laws.

The State of North Rhine-Westphalia was said to have the most stringent air pollution code, and a copy of this code was obtained. A common problem in discussing the compliance of an incinerator with air pollution requirements was that the operator was generally unaware of the measurements or design values involved. This information was known only to the designer and was generally not available.

As far as could be determined, no incinerator testing standards have yet been developed. In Paris, the firm Electricité de France is given the responsibility for the performance testing of the incinerators constructed in the city. This firm is said to have much experience in the operation and testing of municipal power plants and has worked to develop incinerator testing procedures. M. Henri Rousseau is in charge of the testing programs; he reported that when the Paris Issy incinerator was performance tested, the facility was highly instrumented and the data collected were fed into a computer for analysis. M. Rousseau was willing to discuss testing procedures but we were linguistically handicapped.

Remarks

Many of the large incineration facilities' superintendents were formerly marine or ship engineers. These men know the combustion process; the necessity to provide a maximum efficiency with whatever equipment was available aboard ship results in their continuing efforts to improve on their incinerator operations. Many of the following ideas were developed in discussions with these men.

Some plants have unsuccessfully attempted to use closed-circuit television to aid the operator in controlling furnace operation. The black and white TV consoles provide visual patterns of the flame and its development on the refuse bed, but the operators would prefer to have a color picture since this color is the only indicator they have of the existing temperatures.

Many operators are unhappy with the location of the control consoles for the incinerator. It appears that many designers place a greater priority on space utilization than operator convenience, and the result is the installation of the control room on the feeding end of the furnace. The operator must walk to the opposite end of the furnace, view conditions in one or more furnaces, return to the controls, and attempt to recall the adjustments necessary for the individual furnaces. From the operator's viewpoint, it would be best to locate the control console on the discharge end of the furnace, as centrally positioned to the furnace viewing ports as possible. Development of hand- or pocket-sized remote control units for the operator might be considered. While viewing the fire through the observation port, the operator would be able to signal to the central control console, or to a control computer, and make the necessary adjustments while actually viewing the operation of the furnace. Of course, this might not be needed if color TV could be used to provide the necessary information at the central control panel.

Most plants have cranes equipped with strain gages to allow the crane operator to see the weight of the charge he is lifting. The data can be recorded on a strip chart and provide more exact information on furnace charging rates and furnace efficiencies.

The plants were pleasingly designed, clean, and well instrumented, although no unusual instrumentation was noted. In European incinerators as in U.S. incinerators, a relationship was observed between plant cleanliness and operational efficiency. A slightly dusty plant indicates a satisfactory operation; much dust indicates a definite need for improvement of the system; and a very clean plant indicates either an unproven plant or one faced with serious operational

difficulties that allows the men to be diverted from their regular duties.

European construction contracting procedure generally requires performance testing of the facility after completion. Efforts are being made to develop a standardized method of incinerator performance testing. Performance testing, sporadic stack particulate sampling, and boiler water analysis are the only control tests now in use in European incineration, but the need for additional control is recognized.

Industrial Operations

For a variety of reasons most industries attempt to burn as much of their liquid and solid wastes as possible. As with most industrial operations, efforts were made to keep the capital costs for the facility as low as possible, which resulted in the structure housing the facility being as small as possible; in several plants only the refuse receiving area would be enclosed, and the equipment would stand in the open. This resulted in a rather unusual but functional structure.

While these facilities receive smaller quantities of wastes than municipal operations, they take in a greater variety of materials, many of which are hazardous and create special disposal problems. Attempts to use a grate system have generally been unsatisfactory because of large quantities of liquid and/or semisolid wastes and large quantities of material with very high heating values. The system found most satisfactory for industrial waste processing was the rotary kiln design.

The kiln was lined with a thick refractory wall, and by experience a thick coating of molten material maintained inside of the drum was found to extend the refractory life. Operational experience also found that addition of sand to the wastes would help the molten material to adhere to the inside of the drum. Waste-heat recovery equipment was usually installed to utilize the high calorific value of the waste, to provide better operational control, and to produce steam or hot water for in-plant use.

One operation attempted to utilize standard or production-line package boiler units. Preliminary calculations indicated that the capability to quickly and easily remove, repair, and replace the unit might offset expected operational problems. Operators quickly found that the package unit life was shorter than expected and presented so many operational problems that it would have been cheaper and simpler to have designed and built a special boiler.

Industrial solid waste disposal must deal with the same problems and complications that are familiar in industrial liquid waste disposal but with one additional constraint: the final product or residue produced in the solid waste disposal process must be retained on the company property. If the system for solid waste disposal produces a problem-causing residue, this can't be passed on to someone else as when liquid waste effluents are discharged into a body of water.

Waste oil presents a current industrial waste disposal problem in Germany. In the past the government subsidized the operation of old and worn out refineries capable of salvaging the usable portion of waste oil and the destruction of the remainder. The government now plans to discontinue the subsidy, and the problem is not one of disposal technique, but rather the collection and transportation of the old oil to proposed disposal operations. Efforts are being made to define the problem and to determine a solution.

IX. Tipping

IN THE UNITED STATES there is a need for defining and emphasizing the differences between an open dump, a landfill, and a sanitary landfill. Germany is faced with a similar situation except that the Germans do not practice the sanitary landfill technique and this tends to really confuse international solid waste discussions. The German technique known as "geordnite deponie" (orderly depositing) (or controlled tipping), can be likened to a stateside landfill (sanitary landfill without the soil cover).

The general practice seems to be that German cities of over 50,000 population use incineration or composting as the primary method of solid waste disposal. While smaller communities find these techniques expensive, many are seriously considering building, or have already built, such facilities with such justifications as: no deposition land available; that transportation costs to the site would be too great; that there would be potential groundwater pollution problems; or that the land had been reserved by law for a higher use. Population density is a decisive factor, yet there are many small communities that should use the sanitary landfill technique but do not. Why? Germans, just as Americans, have been confused about the difference between an open dump and a controlled tip or sanitary landfill, therefore the public sentiment is such that any deposition is open dumping and must be forbidden. With establishment of the German solid waste program, effort is now being directed to educate the public on the solid waste problem and to encourage development of a regional approach where the combined resources of several small communities could support an effective solid waste management system.

It is paradoxical that the laws forbid deposition of "raw wastes" but fail to set standards or guidelines for evaluating the difference between raw wastes and treated wastes. To evaluate the relationship of a landfill to its environment, an organization that is part of the Institute of Water, Soil and Air Hygiene in Berlin is conducting research studies at a Berlin landfill. The test site consists of 12 cells arranged in an L-shape with the horizontal leg exposed to the atmosphere on both sides; the vertical leg has one side exposed to the atmosphere, and the other side is continuous with the main body of the landfill. The cells have varied types of construction (e.g., variations in compaction, materials used, depth of layers) with each cell instrumented to record the desired data. Of interest is the movement of water into, through, and out of the landfill. The site studies have found that: nearly 90 percent of the surface water moves into the fill; the maximum moisture content occurs with maximum compaction; and loosely placed material reaches higher temperatures and undergoes faster decomposition. In the water movement studies, radioactive salts and a neutron device have been used. The neutron device is similar to that used for highway construction density studies *in situ*, and (like the instrument used in highway construction) there are some calibration difficulties when heterogeneous materials are involved. The research personnel state, however, that the device provides the data they desire.

The Berlin landfill, characteristic of the German-controlled tips, began as an abandoned quarry and has now reached an altitude of about 30 feet above the surrounding grade. While operational appearance is untidy, there is usually a long-range site development plan to control the contours of the operation so that in the end it will be an asset to the community, such as a play-

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ground. Sailplanes or gliders are popular in Germany and the pilots have found that the landfill heat of decomposition produces useful updrafts for their planes, an incidental community benefit from solid waste management.

X. Conclusions

THE CONCLUSIONS drawn from this report might be as long as the report itself. It is hoped that the information has stimulated thought in a number of areas. While the different economies of the United States and other countries result in different approaches to the same problem, it is significant that efforts are now being put forth that may result in major transformations of existing solid waste management systems. A free and rapid exchange of information will be useful to all interested countries.

XI. Addendum

Thessaloniki, Greece

ON ANNUAL LEAVE in northern Greece in June 1968, a member of the U.S. Public Health Service solid wastes program happened to visit a large compost plant in Thessaloniki, Macedonia. The second largest Greek city, with a population of 400,000, Thessaloniki is unique in being the urban seat of the most productive agricultural area of Greece. This is despite the fact that 60 percent of all Macedonian land under cultivation is reported to contain only 2 to 3 percent of organic matter.

Construction of the four-tower Multi-bactor plant in Thessaloniki began in 1964. Experimental compost production was carried on for about two months in 1966 and then was discontinued while auxiliary equipment was added and various adjustments were made. Production started up again in 1967. Two professors of agriculture who were interviewed reported that the compost was of excellent quality. They said that the fertilizer had small quantities of glass and plastic, but that the particle size was very small in comparison to pieces of glass and plastic in other composts. They added that there was no troublesome odor. Although the plant was supposed to produce 100 to 125 tons of compost per day, they said the plant actually turned out about 80 tons per day when in full production, because of frequent mechanical breakdowns.

The Thessaloniki plant is part of AEBOL, manufacturers of organic fertilizers. Although it was reported that AEBOL had made compost successfully in Oporto (Portugal), Verona and Palermo (Italy), and Tripoli (Libya), the AEBOL plant in Thessaloniki was not operating when visited. (Later, a Thessalonikian, who had followed the development of the AEBOL plant as a member of the board of directors, indicated the probable reasons were: the product had not yet been marketed, there were no spare parts for the machinery, and there were no funds at that time to continue plant operation.) The plant was toured with a guide who reported that ordinarily there would be about 100 men employed and that the usual daily input was about 200 truckloads of refuse per day, or approximately 250 tons, 6 days per week. Carried in by the city of Thessaloniki's collection trucks, these loads consisted of the city's domestic refuse as well as some of its industrial solid wastes (mostly agricultural wastes from the city's large canning industry). AEBOL was to pay 8 percent of net compost sales to the municipality of Thessaloniki in return for the refuse. Thessaloniki, the center of Greece's large-scale fruit and vegetable production, has a great potential compost market because of the shortage of animal manure and other organic material that might be used to improve the poor soil.

After the incoming refuse had been weighed on a truck scale, read in the chemistry laboratory, and was dumped into a bin, it was lifted by conveyor belt to a silo with a 24-hour storage capacity. Next it was conveyed through a cylinder that eliminated heavy objects through several hatches in the bottom. The remaining refuse was elevated by conveyor belt where hand sorters removed plastics, large bottles, and containers; an electromagnet removed any steel, iron, or tin plate. Metals were shunted into a baler, which pressed the ferrous metal scrap into briquettes. The compostable material was transferred to a grinding mill and air-sieving device; any large pieces of nylon, plastic, and paper that were removed were incinerated, and the ashes were added to the compost. The fine material was then siloed for

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24 hours and afterward conveyed to one of the four digester towers where a bacterial inoculum (Arthur H. Thomas Co., Philadelphia, U.S.A.) was added. Each tower had 8 stages with a thermometer and sampling door at each stage. After 24 hours the compost emerged from the towers with a moisture content of 45 percent. It was moved by underground conveyor belt to either: (1) a storage pile for bulk sales to farmers, or (2) a dryer and bagging machine where chemical fertilizers were added.

In June 1968, the four-tower AEBOL plant was surrounded by what looked like a sea of compost stacked in plastic bags, shining in the sun.

—CAROL S. LAWSON

XII. Selected List of Contacts and Operations Observed

CONTACTS

Solid Wastes in General

PROFESSOR DR. ING. HABIL. F. PÖPEL
DIPL.-ING. J. WEIDNER
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Technische Hochschule Stuttgart
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Keplerstrasse 11
Postfach 560
Germany

DR. RUDOLPH BRAUN
MR. VON HIRSCHHEYDT
Eidgen. Anstalt fur Wasserversorgung, Abwasserreinigung und Gewasserschutz
CH Zürich
Physikstrasse 5
Switzerland

Compost Sales

MR. D. W. STOLP
DR. TEENSMA
Vuilafvoer Maatschappij
Jac. Obrechtstraat 67
Amsterdam, Holland

Compost-Crop and Soil Effects

DR. CORD TIETJEN
Institut für Humuswirtschaft
3301 Braunschweig FAL
Bundesalle 50
Germany

DR. BOSSE
Bad Kreznach Compost Plant
Bad Kreznach
Germany

Compost and Pathogens

DR. D. STRAUCH
Veterinärhygienischen und Tierseuchen
Institut der Justus-Liebig-Universität
Giessen, Germany

Compost-Nitrogen and Soil Effects

PROFESSOR DR. H. KOEPF
Institut fur Bödenkunde
7000 Stuttgart-Hohenheim
Germany

Tipping (Landfilling)

PROFESSOR LANGER
Institut für Wasser-Boden-Lufthygiene
1 Berlin 33
Corrensplatz 1
Germany

Pneumatic Collection

MR. G. I. FREDHOLM
Chief Engineer
AB Centralsug
Hälsingborgsvägen 4
Stockholm, Sweden

Solid Wastes and the Ruhr Planning Association

DIPL.-ING. W. SCHENKEL
Siedlungsverband
Ruhrkohlenbezirk
43 Essen
Kronprinzenstr. 35
Germany

Incinerator Design

DIPL.-ING. WALTER JOSEPH MARTIN
Director
Joseph Martin Feuerungsbau G.M.B.H.
8000 Munchen 23
Leopoldstr. 248
Germany

[1] The above list of names and addresses is not meant to be a complete list of authorities or sources of information and is only provided as a possible source of information for the subjects listed.

Incinerator Testing

MR. HENRI ROUSSEAU
Electricité de France
T.I.R.U.
134 Boulevard Haussman
Paris 8, France

OPERATIONS OBSERVED

Composting

DENMARK:

Sonderborg
Gladsaxe— MR. K. SUNTUM
MR. M. FABIAN
Dano Company
Ing. Kai Petersen's Fond
Buddinge VAERK
Pr. Soborg
Copenhagen, Denmark

GERMANY:

Baden-Baden— MR. DINK
Bad Kreuznach— MR. BOSSE
Blaubeuren— DR. SPOHN
Duisburg— MR. FRECHEN
Heidelburg— MR. O. HORSTMANN
Kalk— Experimental plant
St. Georgen— MR. GEIGER
Schweinfurt— MR. MEYER AND MR. WINTER
Stuttgart–Möhringen— MR. K. GLOCKNER

HOLLAND:

Arnhem— MR. BRINK
Nijmegen— Manure Composting for Mushrooms
Soest
Wijster— MR. D. W. STOLP (VAM) or MR. FABRIK

SWITZERLAND:

Buchs— MR. GIGER
Chaux-de-Fonds
Hinwell— MR. SCHMID
Turgi

Grinding

FRANCE:

Sarcell

GERMANY:

Neckarsulm— MR. WILLE
Wiesbaden— MR. WITTE

SWITZERLAND:

Barburg

Incineration

FRANCE:

Paris— MR. HENRI ROUSSEAU

GERMANY:

Bad Godesburg
Berlin
Braunschweig— MR. ENGELKE
Düsseldorf— MR. ANDREASON
Essen- Karnap
Frankfurt— MR. BAUMANN and MR. THODE
Hamburg— MR. ONASCH
Kalk— Waste oil burner
Ludwigshafen— Industrial operation; MR. LIEB or MR. SCHALKTER
Munich— MR. STELZA, MR. SALAMON or MR. J. MARTIN
Stuttgart— MR. NOWAK

HOLLAND:

Den Haag— MR. WUSCHERT
Leiden— MR. MAYER
Rotterdam

SWITZERLAND:

Lausanne— MR. MAYER
Geneva— MR. KREOPFLI

Sludge Disposal

GERMANY:

Stuttgart— MR. REUTTER

SWITZERLAND:

Dübendorf— MR. H. FEHLMAN (Plant Designer) and
MR. H. BUHLER (Buhler Co. Representative)
Lausanne
St. Gallen— MR. SEILER

Tipping (Landfilling)

GERMANY:

Braunschweig— MR. ENGELKE
Berlin— PROFESSOR LANGER
Knapsack— Industrial operation
Leverkusen— Industrial operation, DR. FABIAN

Collection

SWEDEN:

Sundbyberg— MR. G. I. FREDHOLM